www.civil guru.net

This is the subtitle of PDF, Use long text here.

This is the subtitle of PDF, Use long text here.

QUANTUM SERIES

For

B.Tech Students of Second Year
of All Engineering Colleges Affiliated to
Dr. A.P.J. Abdul Kalam Technical University,
Uttar Pradesh, Lucknow
(Formerly Uttar Pradesh Technical University)

Energy Science & Engineering

By

Mohd. Aazam Khan **Hareesh Kumar**

Shubham Tyagi

Quantum Page

QUANTUM PAGE PVT. LTD.
Ghaziabad ■ New Delhi

PUBLISHED BY : **Apram Singh**
Quantum Publications®
(A Unit of Quantum Page Pvt. Ltd.)
Plot No. 59/2/7, Site - 4, Industrial Area,
Sahibabad, Ghaziabad-201 010

Phone : 0120 - 4160479
Email : pagequantum@gmail.com **Website: www.quantumpage.co.in**
Delhi Office : 1/6590, East Rohtas Nagar, Shahdara, Delhi-110032

Energy Science & Engineering (Sem-3 & 4)
1st Edition : *2019-20*

Price: Rs. 80/- only

Printed at : Mayank Enterprises, Delhi-110093.

CONTENTS

KOE 033 / KOE 043 : Energy Science & Engineering

1

UNIT

Energy and its Usage

CONTENTS

PART-1

Units and Scales of Energy Use.

CONCEPT OUTLINE

Energy : It is defined as the capacity to exert a force through a distance. It exists in various forms like heat energy, chemical energy, nuclear energy, mechanical energy, etc.

Units of Energy : Energy can be measured in :

1. Joule,
2. Calorie, and
3. kWh.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. What are the various scales of energy ? Where are they used ?

Answer

Various scales of energy that exists are as follows :

1. **Femto (10^{-15}) :** Femto refers to something that is in the 10^{-15} range.
   Uses : Certain specialized medical facilities, have a certain lasers referred to as Femtosecond lasers. So, Femtosecond lasers are laser which are 'on' for of a second and then they go 'off'.
2. **Pico (10^{-12}) :** Pico refers to something that is in the 10^{-12} range.
   Uses : High precision power supply used in laboratories to make very precise measurements of current, voltage and resistance of specific samples.
3. **Nano (10^{-9}) :** Nano refers to something that is in the 10^{-9} range.
   Uses : Electron micrograph is an example of instrument using 10^{-9} range.
4. **Micro (10^{-6}) :** Micro refers to something that is in the 10^{-6} range.
   Uses : In measuring instrument in the fields of science and engineering.
5. **Milli (10^{-3}) :** Milli refers to something that is in the 10^{-3} range.
   Uses : A typical scientific calculator uses power in the scale of 0.1 milli Watt.
6. **Kilo (10^{3}) :** Kilo refers to something that is in the 10^{3} range.

Uses : In solar panels and batteries in Hubble space telescope.

7. **Mega (10^6) :** Mega refers to something that is in the 10^6 range.
   Uses : Used in large vehicles like submarines.
8. **Giga (10^9) :** Giga refers to something that is in the 10^9 range.
   Uses : Modern day mobile phones have built in storage, which are of the order of 16 GB, 64 GB which mean mobile phone store data in several gigabyte.
9. **Tera (10^{12}) :** Tera refers to something that is in the 10^{12} range.
   Uses : Cameras and computers today uses hard disks in the terabyte scale.
10. **Peta (10^{15}) :** Peta refers to something that is in the 10^{15} range.
    Uses : Today's supercomputers operate in hundreds of petaflops.
11. **Exa (10^{18}) :** Exa refers to something that is in the 10^{18} range.
    Uses : 10^{18} is a kind of a quantity that is indicated with prefix exa, the world today uses energy in the range of 500 exa joules.
12. **Zetta (10^{21}) :** Zetta refers to something that is in the 10^{21} range.
    Uses : In 2010 humanity is said to have crossed the 1 zetta byte mark in terms of data created and stored overall. And we might be crossing 7 zetta byte mark by 2020.
13. **Yotta (10^{24}) :** Yotta refers to something that is in 10^{24} range.
    Uses : We can understand this scale when we compare against something in the scale of the galaxies and universe.

PART-2

Mechanical Energy and Transport.

CONCEPT OUTLINE

Mechanical Energy : It is the sum of potential energy and kinetic energy. It is the energy associated with the motion and position of an object, e.g. a moving car possesses mechanical energy due to its motion.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.2. **Define kinetic energy and also derive an expression for it.**

Answer

A. Kinetic Energy : The energy that a body possesses by virtue of its motion is known as kinetic energy.

Mathematically, $KE = \frac{1}{2} m v^2$

B. Mathematical Expression for Kinetic Energy :

1. Consider a body of mass m starting from rest. Let it be subjected to an accelerating force F and after covering a distance s, its velocity becomes v.
   $\therefore$ Initial velocity, $u = 0$
2. Now, work done $= Fs$ ...(1.2.1)
3. We know that, $F = ma$
4. Substituting the value of F in eq. (1.2.1), we have
   Work done $= m \times (as)$ ...(1.2.2)
5. From equation of motion, we have
   $v^2 - u^2 = 2as$ or $v^2 - 0^2 = 2as$ ($\because u = 0$)
   $as = \frac{v^2}{2}$
6. Substituting the value of as in eq. (1.2.2), we get
   Work done $= m \frac{v^2}{2}$
7. But work done on the body is equal to KE possessed by the body.
   $\therefore$ $KE = \frac{1}{2} m v^2$

Que 1.3. **Define potential energy and also give principle of conservation of mechanical energy.**

Answer

A. Potential Energy : It is defined as the capacity to do work by virtue of its position.

Mathematically, $PE = mgh$

B. Principle of Conservation of Mechanical Energy :

1. If a body is subjected to a conservative system of forces then its mechanical energy remains constant for any position in the force field.
2. Consider a body either sliding down a smooth incline or freely falling. Since it is initially at rest, all of its energy is potential energy.
3. As it accelerates downwards, some of its potential energy is converted into kinetic energy.

4. At the bottom of the incline or at the ground level, the energy will be purely kinetic, assuming the bottom of the slope or the ground level as the datum for potential energy.
5. By the principle of conservation of energy, we see that the loss in potential energy is equal to the gain in kinetic energy.

   Mathematically,

   $$(PE)_i - (PE)_f = (KE)_f - (KE)_i$$
6. On rearranging, we have

   $$(PE)_i + (KE)_i = (PE)_f + (KE)_f$$

   $$(PE) + (KE) = \text{Constant}$$
7. Thus, we see that the total mechanical energy, *i.e.*, sum of potential and kinetic energies remain constant. This is known as principle of conservation of mechanical energy.

PART-3

Heat Energy : Conversion between Heat and Mechanical Energy.

CONCEPT OUTLINE

Heat Energy : It is the result of the movement of fine particles called atoms, molecules or ions in solids, liquids and gases. It can be transferred from one object to another.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.4. **What is a heat reservoir or thermal energy reservoir? Also define heat source and heat sink.**

Answer

A. Heat Reservoir : It is defined as the source of infinite heat energy and a finite amount of heat absorbed or heat rejected from the heat reservoir will not have any effect on its temperature *i.e.*, heat reservoir is maintained at a constant temperature.

B. Heat Source :

1. Thermal reservoir which supplies heat to a system is known as source.
2. This is at high temperature, e.g., boiler furnace, combustion chamber, nuclear reactor etc.

C. Heat Sink :

1. Thermal reservoir which absorbs heat from a system is known as sink.
2. This is at low temperature, e.g., ocean, river, atmospheric air.

Que 1.5. **Discuss in short about the heat engine.**

Answer

1. Heat engine is defined as a thermodynamic device which is used for continuous production of work from heat when operating in a thermodynamic cyclic process.
2. Both heat and work interactions occur across the boundary of this device, e.g., internal combustion engines, external combustion engines, gas turbines etc.
3. Consider a heat engine which receives Q_1, from heat source at T_1 temperature and produces mechanical work W.
4. The remainder of energy is rejected to heat sink at T_2 temperature.

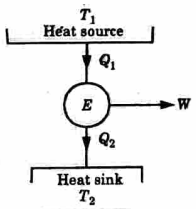


Fig. 1.5.1.

5. From the principle of conservation of energy,

   $$Q_1 = W + Q_2$$

   or $$W = Q_1 - Q_2$$
6. Thermal efficiency, $\eta = \dfrac{\text{Net work output}}{\text{Heat input (supplied)}} = \dfrac{W}{Q}$

   $$\eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$
7. Thermal efficiency is the measure of performance of a heat engine.

PART-4

Electromagnetic Energy : Storage, Conversion, Transmission and Radiation.

This is the subtitle of PDF, Use long text here.

CONCEPT OUTLINE

Electromagnetic Energy : It is a form of energy that is reflected or emitted from objects in the form of electrical and magnetic waves that can travel through space.

Electromagnetic Storage Devices :

1. Capacitor, and
2. Superconducting magnetic energy storage (SMES).

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.6. Write a short note on capacitor.

Answer

1. A capacitor has two parallel plates or electrodes to which we connect an external battery. And in the middle we have a dielectric material as shown in Fig. 1.6.1.

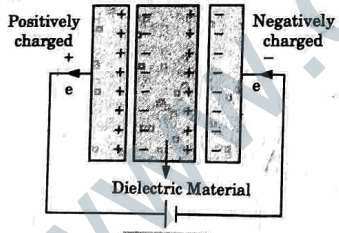


Fig. 1.6.1.

2. Electrons start entering one plate and exiting other. So, one plate becomes positively charged and other negatively charged. Then correspondingly the side of the dielectric material that faces the negative electrode becomes positively charged, and the side of the dielectric material that is facing the positive electrode becomes negatively charged.
3. There is overall charge neutrality because of just the same amount of positive and negative charge.
4. Charge is given as, $Q = CV$

   Where, V = Voltage

   C = Capacitance in Farad.

5. The energy being stored is in the form of electrical energy and there is no chemical change.
6. Regions in capacitor are flat. So, this is the way in which the capacitor is functioning and in this process energy is stored.

Que 1.7. Discuss in brief about superconducting magnetic energy storage (SMES).

Answer

1. Superconducting magnetic energy storage (SMES) systems store energy in a magnetic field created by the flow of direct current through a superconducting coil.
2. A SMES system comprises a superconducting coil in a cryogenic enclosure, an electronic converter to match the DC power in the coil to the AC on the grid, and an electronic switch to control the flow of current into and out of the coil.
3. The superconducting coil is charged by applying a DC voltage which causes the current through the coil to increase.
4. When the current reaches its working value an electronic switch isolates the DC supply and short-circuits the coil. Because the coil has zero resistance, the current continues to circulate without losses and with no heat generation.
5. To release the stored energy, the sw h is opened and the coil discharges through the converter, yielding AC power which can be fed to the grid.
6. Their primary advantage compared to other types of energy storage is their very short reaction time and ability to provide high power for short periods.
7. Because they can be switched on with virtually no time delay, SMES systems can counteract abrupt changes in demand for applications where even the shortest interruptions are unacceptable.

Que 1.8. Briefly describe about the transformer with suitable sketch.

Answer

1. Transformer is a static device which transfers energy from one circuit to another which are electrically isolated but magnetically coupled without change in frequency.
2. Transformer provides link between generator and transmission line and between transmission line and distribution system. And finally transformers are used to deliver energy to load.
3. The transformer isolates the expensive generator from the exposed overhead power grid.

4. The transient over voltages caused by atmospheric disturbance will propagate along the lines as waves, having high crests and steep voltage fronts and velocities slightly less than that of light.

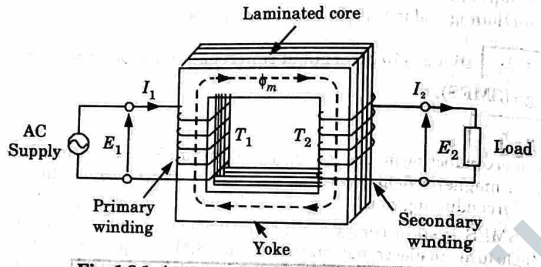


Fig. 1.8.1. Arrangement of a simple transformer.

5. As these waves are being reflected at the transformer terminals, high voltage amplitude will be built up which will stress the insulation of the transformer than in a generator windings.
6. Transformers come in sizes ranging from distribution transformers rated a few kVA to huge three phase rating in excess of 1000 MVA.

Que 1.9. **Write a short note on electromagnetic radiation.**

Answer

1. Electromagnetic radiation is an electric and magnetic disturbance traveling through space at the speed of light.
2. It contains neither mass nor charge but travels in packets of radiant energy called photons, or quanta.
3. Examples of EM radiation include radio waves and microwaves, as well as infrared, ultraviolet, gamma, and *X*-rays.
4. Some sources of EM radiation include sources in the cosmos e.g., the sun and stars, radioactive elements, and manufactured devices. EM exhibits a dual wave and particle nature.
5. The energy of electromagnetic radiation is quantified by an electron volt (eV), where 1 eV describes the energy gained by an electron as it is accelerated through a potential difference of 1 volt.

PART-5

Introduction to the Quantum, Energy Quantization.

CONCEPT OUTLINE

Wave Particle Duality : According to Einstein, the energy of light is concentrated in small bundles called photon. Hence, light behaves as a wave on one hand and as a particle on the other hand. This nature of light is known as dual nature, while this property of light is known as wave particle duality.

Wave Function and its Significance : The wave function ψ is described as mathematical function whose variation builds up matter waves. $|\psi|^2$ defines the probability density of finding the particle within the given confined limits.

Schrodinger's Wave Equation : This wave equation is a fundamental equation in quantum mechanics and describes the variation of wave function ψ in space and time.

Quantization : The process of restricting the possible values of a physical quantity to a set of discrete values is called quantization.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.10. **What are de Broglie's waves or matter waves ?**

Answer

1. When a material particle moves in a medium, a group of waves is associated with it due to which it shows the wave particle duality. These waves are known as matter waves or de Broglie waves.
2. According to de Broglie's concept, each material particle in motion behaves as waves, having wavelength λ associated with moving particle of momentum p.

$$\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$$

$$\text{Wave nature} \propto \frac{1}{\text{Particle nature}}$$

Que 1.11. **Derive time independent Schrodinger wave equation.**

Answer

1. Consider a system of stationary wave to be associated with particle and the position coordinate of the particle (x, y, z) and ψ is the periodic displacement of any instant time 't'.

2. The general wave equation in 3D in differential form is,

$$\nabla^2\psi = \frac{1}{v^2}\frac{\partial^2\psi}{\partial t^2} \quad ...(1.11.1)$$

Where, v = Velocity of wave, and

$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ = Laplacian operator.

3. The wave function may be written as,

$$\psi = \psi_o e^{-i\omega t} \quad ...(1.11.2)$$

4. Differentiate eq. (1.11.2) wrt time, we get

$$\frac{\partial\psi}{\partial t} = -i\,\omega\,\psi_o e^{-i\omega t} \quad ...(1.11.3)$$

5. Again differentiating eq. (1.11.3),

$$\frac{\partial^2\psi}{\partial t^2} = +i^2\omega^2\psi_o e^{-i\omega t}$$

$$\frac{\partial^2\psi}{\partial t^2} = -\omega^2\psi \quad ...(1.11.4)$$

6. Putting these value in eq. (1.11.1),

$$\nabla^2\psi = \frac{-\omega^2}{v^2}\psi \quad ...(1.11.5)$$

7. But $\omega = 2\pi\nu = \frac{2\pi v}{\lambda} \Rightarrow \frac{\omega}{v} = \frac{2\pi}{\lambda}$

8. Eq. (1.11.5) becomes,

$$\nabla^2\psi = -\frac{4\pi^2}{\lambda^2}\psi \quad ...(1.11.6)$$

9. From de-Broglie's wavelength, $\lambda = \frac{h}{mv}$

Then $\nabla^2\psi = \frac{-4\pi^2 m^2 v^2}{h^2}\psi \quad ...(1.11.7)$

10. If E and V are the total and potential energies of a particle and E_k is kinetic energy, then

$$E_k = E - V \text{ or } \frac{1}{2}mv^2 = E - V \quad \text{or} \quad m^2v^2 = 2m(E-V)$$

11. Now eq. (1.11.7) becomes,

$$\nabla^2\psi = \frac{-4\pi^2 2m[E-V]\psi}{h^2} \qquad \left[\text{Since } \hbar = \frac{h}{2\pi}\right]$$

$$\therefore \nabla^2\psi + \frac{2m[E-V]\psi}{\hbar^2} = 0 \quad ...(1.11.8)$$

This is required time-independent Schrodinger wave equation.

PART-6
Energy in Chemical Systems and Processes, Flow of CO_2

CONCEPT OUTLINE

Fuel Cell : A fuel cell is an electrochemical cell that converts the chemical energy of a fuel into electricity.

Questions-Answers
Long Answer Type and Medium Answer Type Questions

Que 1.12. Discuss the application and economic aspect of fuel cells.

AKTU 2019-20, Marks 10

Answer

A. Applications of Fuel Cell : Various applications of fuel cells are as follows :

i. Portable Applications : These include :

1. Portable power generators,
2. Consumer electronics,
3. Portable military equipments, etc.

ii. Transportation Applications : These include :

1. Auxiliary power units,
2. Light traction vehicles,
3. Marine propulsion, etc.

iii. Stationary Applications : These include :

1. Distributed power generation,
2. Combined heat and power,
3. Back up power supply, etc.

B. Economic Aspects of Fuel Cells :

1. As a new energy technology, fuel cells have not yet significantly penetrated the energy market. Cost, durability, and reliability are the main challenges in the commercialization of fuel cells.
2. The manufacturing life cycle and value chain represent the production procedure and cost of fuel cycle.

3. The manufacturing cost includes the design, materials, component fabrication and assembly, labour, and equipment capital, which is required in the overall assembly of custom fabricated and commercially produced fuel cells.
4. The stack, air management, fuel management, and thermal management were the most expensive parts of the system. The stack system assembly and balance made up 14 % of the total cost.
5. It is clear that most studies on existing fuel cell costs are based only on stack manufacturing costs, without consideration of repair and maintenance costs. However, the cost of repair and maintenance is necessary for stack service and end-user acceptance.

Que 1.13. Write short note on following :

a. Lithium-ion battery.
b. Nickel metal hydride.

Answer

a. Lithium-ion Battery :

1. It is the most popular battery at this point of time. It is lighter than the nickel metal hydride battery because lithium is the lightest metal.
2. Therefore, it has much better energy density. It is rechargeable. Its ion part makes it rechargeable and it can also discharge over period of time if not used.
3. Reactions of Lithium-ion battery are :

$$LiC_6 \longrightarrow C_6 + Li^+ + e^-$$
$$CoO_2 + Li^+ + e^- \longrightarrow LiCoO_2$$

4. It uses lithium in carbon as the anode, so when it discharges lithium leaves the anode and releases the electron which goes into the external circuit.
5. Then the lithium ion which comes through the electrolyte and the electrons which come through the external circuit react with cobalt oxide (CoO_2) and form lithium cobalt oxide ($LiCoO_2$). This reaction is reversible. So, it is the rechargeable battery.

b. Nickel Metal Hydride (NiMH) Battery :

1. It is rechargeable battery. This is non toxic so it can replace alkaline as well as nickel cadmium batteries. This does not have the memory effect.
2. It has high capacity and high energy density and its energy density approaches that of lithium ion.
3. It can self-discharge means it will slowly discharge if we do not use it.
4. Reactions of nickel metal hydride battery are :

$$MH + OH^- \longrightarrow M + H_2O + e^-$$
$$NiO(OH) + H_2O + e^- \longrightarrow Ni(OH)_2 + OH^-$$

Que 1.14. Explain the working of molten carbonate fuel cells using appropriate diagram and write the various chemical reactions involved in this type of fuel cell.

Answer

1. It uses an electrolyte, which is a molten mixture of carbonate salts.
2. Two mixtures commonly used are :
   a. Lithium carbonate and potassium carbonate, and
   b. Lithium carbonate and sodium carbonate.

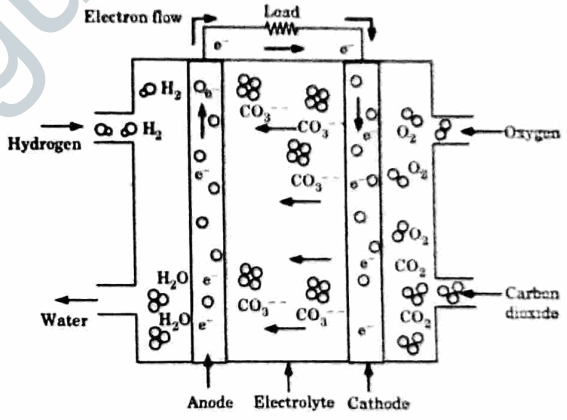


Fig. 1.14.1. Molten carbonate fuel cell.

3. Since, these salts can act as electrolytes only in liquid phase, the operating temperature should be as high as 650 °C.
4. Due to high temperature, these salts melt and become conductive to carbonate ions (CO_3^{--}).
5. These ions flow from the cathode to the anode where they combine with hydrogen to give water, carbon dioxide and electrons.
6. The electrons flow through external circuit and reaches to cathode, generating electricity and byproduct heat.
7. The reactions are given below :

Anode reaction : $CO_3^{--} + H_2 \longrightarrow H_2O + CO_2 + 2e^-$
Cathode reaction : $CO_2 + 1/2\ O_2 + 2e^- \longrightarrow CO_3^{--}$

Total reaction : $H_2 + 1/2\,O_2 + CO_2 \longrightarrow H_2O + CO_2$

8. The emf produced by each cell is theoretically 1 V and actual emf of 0.8 V at 700 °C and the expected efficiency is about 60 %.

PART-7

Entropy and Temperature.

CONCEPT OUTLINE

Entropy : Entropy is defined as the quantitative measure of disorder or randomness in a system. It deals with the transfer of heat energy within a system.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.15. **Discuss entropy.**

Answer

1. From Clausius theorem, cyclic integral of $\frac{\delta Q}{T}$ for a reversible process is zero. The term $\frac{\delta Q}{T}$ is called entropy and its change from state 1 to state 2 during reversible process is given as,

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_{rev} = \int_1^2 ds = s_2 - s_1$$

2. Entropy is a measure of degree of randomness of molecules comprising a system. Higher the disorderness, greater is the increase in entropy.
3. In other words, entropy is the function of quantity of heat which shows the possibility of conversion of that heat into work. On heat addition entropy of system increases and on heat rejection, it decreases.

Que 1.16. **Explain entropy principle.**

Answer

1. According to this principle, entropy of an isolated system either increases or in the limit remains constant.

2. An isolated system does not undergo any energy interaction (*i.e.*, work or heat energy) with its surroundings, and the total energy of all the possible states remains constant. Therefore for an isolated system,

$$\delta Q = 0$$

$$\therefore \quad (ds)_{isolated} \geq 0$$

3. If the process is reversible, $(ds)_{isolated} = 0$ and if the process is irreversible, $(ds)_{isolated} > 0$.
4. From above we see that the entropy of an isolated system can never decrease. It always increases with every irreversible process and remains constant during a reversible process. This is called principle of entropy increase.

PART-8

Carnot and Stirling Heat Engines.

CONCEPT OUTLINE

Carnot Engine : It is a theoretical engine which works on the Carnot cycle.
Stirling Engine : It is a heat engine which is operated by a cyclic compression and expansion of air or other gas at different temperatures such that there is a net conversion of heat energy to mechanical work. It works on Stirling cycle.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.17. **Explain the Carnot vapour power cycle with *T-s* diagram. Also find out the efficiency of Carnot cycle.**

Answer

A. Carnot Cycle :

1. It is an ideal cycle having highest thermodynamic efficiency. Carnot cycle is shown in Fig. 1.17.1.
2. Various processes of Carnot cycle are as follows :

a. **Process 1-2 :** It is reversible isothermal heat addition process in the boiler.
b. **Process 2-3 :** It is reversible adiabatic expansion process in steam turbine.
c. **Process 3-4 :** It is reversible isothermal heat rejection process in the condenser.

d. Process 4-1 : It is reversible adiabatic compression process or pumping process in feed water pump.

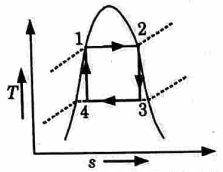


Fig. 1.17.1. Carnot vapour power cycle.

B. Efficiency :

1. Net work = Turbine work – Pump work

   For unit mass flow,

$$W = (h_2 - h_3) - (h_1 - h_4)$$

2. Heat added in process 1-2,

$$Q_{1-2} = h_2 - h_1$$

3. Thermal efficiency = $\frac{\text{Net work}}{\text{Heat added}}$

$$\eta_{Carnot} = \frac{(h_2 - h_3) - (h_1 - h_4)}{(h_2 - h_1)}$$

$$= 1 - \frac{h_3 - h_4}{h_2 - h_1}$$

4. Heat rejected in process 3-4,

$$Q_{3-4} = h_3 - h_4$$

So, $$\eta_{Carnot} = 1 - \frac{Q_{3-4}}{Q_{1-2}}$$

5. Heat added or rejected can also be expressed in terms of temperature and entropy, so

$$Q_{3-4} = T_3 (s_3 - s_4)$$

and $$Q_{1-2} = T_1 (s_2 - s_1)$$

$$\eta_{Carnot} = 1 - \frac{T_3 (s_3 - s_4)}{T_1 (s_2 - s_1)}$$

6. As we know, $s_1 = s_4$ and $s_2 = s_3$

   So, $$s_3 - s_4 = s_2 - s_1$$

$$\eta_{Carnot} = 1 - \frac{T_3}{T_1}$$

Que 1.18. Describe the Stirling cycle.

Answer

1. Stirling cycle consists of two isothermal and two constant volume processes. It is externally reversible cycle.
2. Heat rejection and heat addition takes place at constant volume.
3. This cycle has mean effective pressure greater than Carnot cycle. But efficiency in ideal case is equal to the Carnot cycle.
4. From Fig. 1.18.1(*b*), it is clear that amount of heat addition and rejection during constant volume process is same. So efficiency of cycle is given as,

$$\eta_{Stirling} = \frac{T_3 - T_1}{T_3}$$

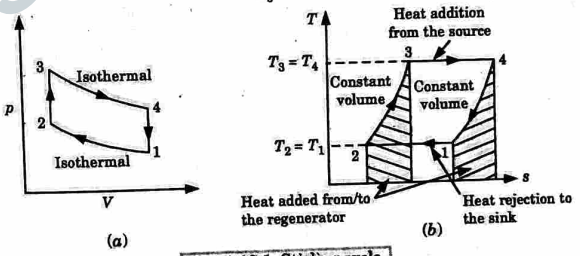


Fig. 1.18.1. Stirling cycle.

5. In practical use, Stirling cycle incorporated with a heat exchanger, which absorb the heat rejected during constant volume process and supplies back to the cycle in heat addition during constant volume.
6. So amount of heat transfer through heat exchanger (absorb heat and heat supplied back to cycle) is same. But efficiency of heat exchanger is not 100 %. So efficiency of Stirling cycle will be less than the Carnot cycle.

PART-9

Phase Change Energy Conversion, Refrigeration and Heat Pump.

CONCEPT OUTLINE

Phase Change : Phase change process is the change of material physical state from one state to another like solid to liquid and vice-versa. Material utilizes its latent heat during phase change processes.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.19. **Define refrigeration. State the application of refrigeration.** **AKTU 2019-20, Marks 10**

Answer

A. Refrigeration :

1. Refrigeration means the cooling or removal of heat from a system.
2. It is the science of producing and maintaining temperatures below that of the surrounding atmosphere *i.e.*, removal of heat from a substance under controlled conditions.
3. The equipment employed to maintain the system at a low temperature is termed as refrigerating system and the system which is kept at lower temperature is called refrigerated system.

B. Applications of Refrigeration :

1. Making of ice.
2. It is used in transportation of food at a required temperature.
3. It is used in industrial and comfort air conditioning.
4. It is used in processing food products and beverages.
5. It is used in manufacturing and treatment of metals.

Que 1.20. **Write short note on the following :**

a. Heat pump.
b. Refrigerator.

Answer

a. Heat Pump :

1. A heat pump is a reversed heat engine. It receives heat from a low temperature reservoir (source) and rejects it to a high temperature reservoir (sink).
2. This transfer of heat from a low temperature body to a high temperature one is essentially a non-spontaneous process. And that calls for the help of an external work which is supplied to the heat pump (Fig. 1.20.1).
3. A heat pump extracts Q_2 amount of heat from the low temperature (T_2) source and delivers Q_1 amount of heat to the high temperature (T_1) sink by consuming W amount of external work.

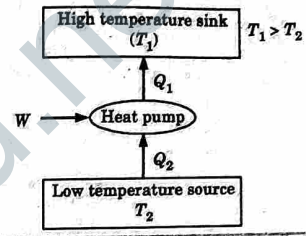


Fig. 1.20.1. A schematic diagram of a heat pump.

4. Coefficient of performance,

$$\text{COP} = \frac{\text{Desired effect}}{\text{Work input}} \quad \text{...(1.20.1)}$$

5. Now, the desired effect for a heat pump is to supply heat Q_1 to the hot body. Therefore,

$$\text{COP}_{HP} = \frac{Q_1}{W} \quad \text{...(1.20.2)}$$

6. From the first law of thermodynamics,

$$\sum_{cycle} Q = \sum_{cycle} W$$

$$\therefore \quad Q_1 - Q_2 = W$$

Hence, eq. (1.20.2) becomes

$$\text{COP}_{HP} = \frac{Q_1}{Q_1 - Q_2}$$

b. Refrigerator :

1. A refrigerator is similar to a heat pump. It operates as a reversed heat engine.
2. Its duty is to extract heat as much as possible from the cold body/space and deliver the same to high temperature body/surroundings.
3. The desired effect of a refrigerator, under a steady state, is to pump out the heat in the same rate as is infiltrating into the system (Q_2). And in order to do so, the refrigerator takes up W amount of external work (Fig. 1.20.2).
4. The desired effect of a refrigerator is to remove Q_2 heat infiltrating into the cold space.
5. By using the external work, it rejects Q_1 heat to the high temperature reservoir (surroundings). Therefore,

$$\text{COP}_{ref} = \frac{\text{Desired effect}}{\text{Work input}} = \frac{Q_2}{W} \quad \text{...(1.20.3)}$$

This is the subtitle of PDF, Use long text here.

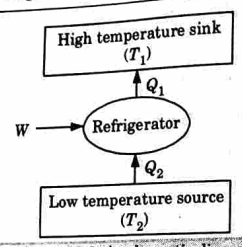


Fig. 1.20.2. A schematic diagram of a refrigerator.

6. From the first law of thermodynamics,

$$\sum_{cycle} Q = \sum_{cycle} W$$

$$\therefore \quad Q_1 - Q_2 = W$$

7. Hence, eq. (1.20.3) becomes

$$COP_{ref} = \frac{Q_2}{Q_1 - Q_2} \qquad ...(1.20.4)$$

Where, Q_2 is the heat infiltrating into the cold space of the refrigerator.

PART-10

Internal Combustion Engines.

CONCEPT OUTLINE

IC Engines : The engines in which the combustion takes place inside the engine or within the cylinder are known as internal combustion engines.

Types of IC Engine Based on Ignition :

1. Spark Ignition (SI) engine.
2. Compression Ignition (CI) engine.

Four Stroke Engines : The engines in which cycle of operation completed in four stroke of piston or two revolution of crankshaft are known as four stroke engines.

Two Stroke Engines : The engines in which cycle of operation completes in two stroke of piston or one revolution of crankshaft are known as two stroke engines.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.21. **Classify the internal combustion engine.**

Answer

Internal combustion engine can be classified as follows :

i. According to Basic Engine Design :

1. Reciprocating engine, and
2. Rotary engine.

ii. According to Working Cycle :

1. Otto cycle, and
2. Diesel cycle.

iii. According to Number of Stroke :

1. Four stroke engine, and
2. Two stroke engine.

iv. According to Fuel Employed :

1. Gasoline or petrol engine,
2. Diesel engine,
3. LPG engine, and
4. CNG engine.

v. According to Fuel Supply and Mixture Preparation :

1. Carbureted type, and
2. Injection type.

vi. According to Method of Ignition :

1. Battery ignition, and
2. Magneto ignition.

vii. According to Method of Cooling :

1. Water cooled engine, and
2. Air cooled engine.

viii. According to Cylinder Arrangement :

1. Inline engine,
2. V-engine, and
3. Radial engine.

Que 1.22. **Describe the basic terminology used in internal combustion engine.**

Answer

Terms used in internal combustion engine are as follows :

i. **Cylinder Bore :** It is the nominal inner diameter of the working cylinder. It is represented by D.

ii. **Piston Area :** It is the area of a circle of diameter equal to the cylinder bore.

iii. **Stroke :** The distance travelled by piston from top dead centre to bottom dead centre is known as stroke.

iv. **Bottom Dead Centre (BDC) :** It is the dead centre when the piston is nearest to the crankshaft or lowest position of the piston towards the crank end side of cylinder.

v. **Top Dead Centre (TDC) :** It is the dead centre when the piston is farthest from the crankshaft or top most position of the piston towards cover end side of cylinder.

vi. **Displacement Volume (or Piston Swept Volume) :**

1. This is the volume swept by the piston moving from one dead centre to other.
2. It is calculated as the product of piston area and stroke.

$$v_s = \text{Piston area } (A) \times \text{Stroke } (L)$$

$$= \frac{\pi}{4} D^2 L$$

vii. **Clearance Volume :** The volume contained in the cylinder above the top of the piston when the piston is at top dead centre is called clearance volume.

viii. **Cylinder Volume :**

1. The sum of swept volume and clearance volume is known as cylinder volume.

ix. **Compression Ratio :**

1. This is defined as the ratio of the volume at the beginning of compression to the volume at the end of compression.

$$r = \frac{v_c + v_s}{v_c} = 1 + \frac{v_s}{v_c}$$

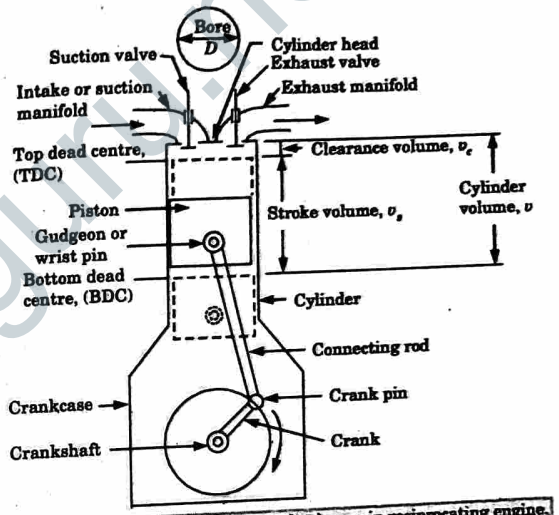


Fig. 1.22.1. Important positions and volumes in reciprocating engine.

Que 1.23. How internal combustion engines work ?

AKTU 2019-20, Marks 10

Answer

Working of internal combustion four stroke spark ignition engine is as follows :

a. **Suction Stroke :**

1. Suction stroke (Fig. 1.23.1) starts when the piston is at top dead centre position and about to move toward bottom dead centre.
2. During this stroke, inlet valve is open and outlet valve is closed.
3. Due to the suction created by downward motion of the piston, charge consists of mixture of air and fuel drawn into the cylinder.
4. At the end of suction stroke, both the inlet and outlet valves are closed.

b. **Compression Stroke :**

1. The fresh charge taken into the cylinder during the suction stroke is compressed during the return stroke of the piston.

2. In this stroke, both the inlet and outlet valves remain closed.
3. Just before the end of the compression stroke, mixture of air and fuel is ignited with the help of spark plug.
4. Burning takes place when the piston is almost at top dead centre.
5. During the burning process, chemical energy of the charge is converted into sensible energy and producing a temperature rise of about 2000 °C and pressure is also increased.

c. Expansion or Working Stroke :

1. Due to high pressure, burnt gases forces the piston towards the bottom dead centre so power is obtain during this stroke.
2. Both pressure and temperature decreases during this stroke.
3. In this stroke, both the valves remain closed.

d. Exhaust Stroke :

1. In this stroke, inlet valve is closed and outlet valve is open.
2. Piston moving from bottom dead centre to top dead centre and burnt gases sweep out from the cylinder.

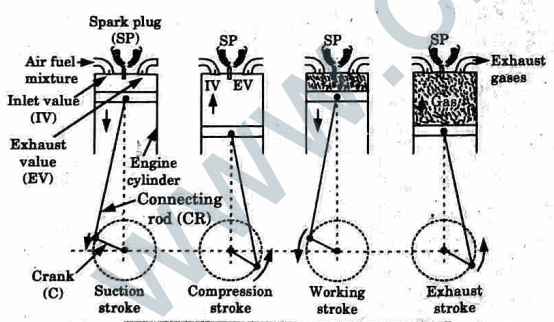


Fig. 1.23.1. Four stroke Otto cycle engine.

Que 1.24. **Compare the SI and CI engine.**

Answer

S. No.	Description	SI Engine	CI Engine
1.	Basic cycle	Otto cycle	Diesel cycle
2.	Fuel used	Gasoline (petrol)	Diesel
3.	Ignition	Spark plug is used.	Self ignition due to high pressure and temperature caused by compression of air.
4.	Compression ratio	6 to 10	14 to 22
5.	Weight	Lighter	Heavier
6.	Speed	High speed	Low speed
7.	Efficiency	Lower efficiency due to low compression ratio.	Higher efficiency due to high compression ratio.

PART-11

Steam and Gas Power Cycles.

CONCEPT OUTLINE

Steam Power cycles : These are the cycles which uses steam as their working fluid. Rankine cycle is the example of steam power cycle.
Gas Power Cycles : These are the cycles which use air or gas as their working fluid. Otto cycle, Diesel cycle, Bryton cycle are the examples of gas power cycles.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.25. **Describe the different operations of Rankine cycle. Also derive the expression for its efficiency.**

Answer

A. Rankine Cycle :

1. Rankine cycle is the theoretical steam cycle on which the steam turbine (or engine) works.
2. The Rankine cycle is shown in Fig. 1.25.1. It consists of following processes :

a. **Process 1-2 :** Adiabatic expansion (in turbine).
b. **Process 2-3 :** Isobaric heat release (in condenser).
c. **Process 3-4 :** Adiabatic pumping (in pump).
d. **Process 4-1 :** Isobaric heat addition (in boiler).

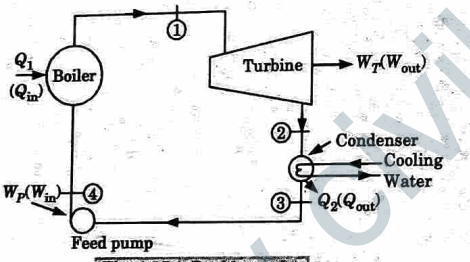


Fig. 1.25.1. Rankine cycle.

3. Fig. 1.25.2 shows *T-s* diagram of Rankine cycle.

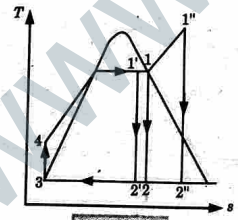


Fig. 1.25.2.

B. Efficiency of Rankine Cycle :

1. Consider 1 kg of fluid applying steady flow energy equation.

i. For boiler :

$$h_{f4} + Q_1 = h_1$$
$$Q_1 = h_1 - h_{f4} \quad \text{...(1.25.1)}$$

ii. For turbine :

$$h_1 = W_T + h_2$$
$$W_T = h_1 - h_2 \quad \text{...(1.25.2)}$$

iii. For condenser :

$$h_2 = Q_2 + h_{f3}$$
$$Q_2 = h_2 - h_{f3} \quad \text{...(1.25.3)}$$

iv. For feed pump :

$$h_{f3} + W_P = h_{f4}$$
$$W_P = h_{f4} - h_{f3} \quad \text{...(1.25.4)}$$

2. Efficiency of Rankine cycle is given by,

$$\eta_{Rankine} = \frac{W_{net}}{\text{Heat supplied}} = \frac{W_T - W_P}{Q_1}$$
$$= \frac{(h_1 - h_2) - (h_{f4} - h_{f3})}{(h_1 - h_{f4})} \quad \text{...(1.25.5)}$$

3. Using general property relation for adiabatic compression,

$$Tds = dh - vdp \qquad (\because ds = 0)$$
$$dh = vdp$$

or $\Delta h = v\Delta p$ (Since change in volume is negligible.)

or $h_{f4} - h_{f3} = v_3 (p_1 - p_2)$

4. The feed pump term $(h_{f4} - h_{f3})$ being a small quantity in comparison with turbine work, W_p, is usually neglected, especially, when the boiler pressures are low.

Then, $\eta_{Rankine} = \dfrac{h_1 - h_2}{h_1 - h_{f4}}$

Que 1.26. Explain Brayton cycle and obtain expression for efficiency in terms of pressure and temperature ratio.

Answer

A. Brayton Cycle :

1. It is a theoretical cycle for gas turbines and also known as constant pressure cycle for a perfect gas.
2. The basic components of a Brayton cycle are shown in Fig. 1.26.1.

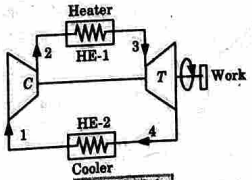
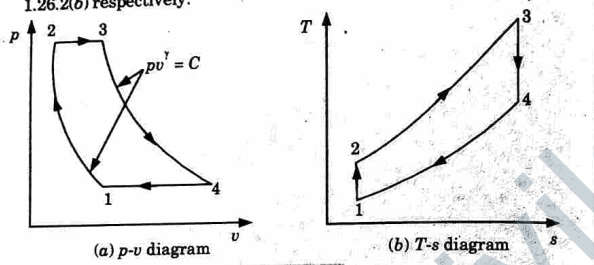


Fig. 1.26.1.

3. There occur two isentropic processes and two constant pressure processes. Compression and expansion of working fluid is done by isentropic process while addition and rejection of heat is done at constant pressure.
4. Brayton cycle on p-v and T-s diagram is shown in Fig. 1.26.2(a) and 1.26.2(b) respectively.



(a) p-v diagram (b) T-s diagram

Fig. 1.26.2.

5. Brayton cycle shows following processes :
   1-2 : Adiabatic compression.
   2-3 : Constant pressure heat addition.
   3-4 : Adiabatic expansion.
   4-1 : Constant pressure heat rejection.
6. Now, Work done / cycle = Heat added/cycle – Heat rejected/cycle
   Heat added in process 2–3 = $mC_p(T_3 - T_2)$
   Heat rejected in process 4–1 = $mC_p(T_4 - T_1)$
   Work done / cycle = $mC_p(T_3 - T_2) - mC_p(T_4 - T_1)$

B. Efficiency of Brayton Cycle :

1. Efficiency, $\eta_{\text{air-standard}} = \dfrac{\text{Work done / cycle}}{\text{Heat addition / cycle}}$

$$= \frac{mC_p(T_3 - T_2) - mC_p(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

$$\eta_{\text{air-standard}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \quad \ldots(1.26.1)$$

2. From process 1–2,

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \qquad \left(\because \frac{p_2}{p_1} = r_p = \text{Pressure ratio}\right)$$

$$T_2 = T_1 (r_p)^{\frac{\gamma-1}{\gamma}}$$

3. Similarly, from process 3–4,

$$T_3 = T_4 (r_p)^{\frac{\gamma-1}{\gamma}}$$

4. Putting the values of T_2 and T_3 in eq. (1.26.1), we get

$$\eta_{\text{air-standard}} = 1 - \frac{T_4 - T_1}{T_4(r_p)^{\frac{\gamma-1}{\gamma}} - T_1(r_p)^{\frac{\gamma-1}{\gamma}}} = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}}$$

PART-12

Physics of Power Plant, Solid State Phenomena including Photo, Thermal and Electric Aspects.

CONCEPT OUTLINE

Solid State Phenomena : It finds out the fundamentals of the structure and their influence on the properties of solid.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.27. List the factors which should be considered while designing a power plant.

Answer

Following factors should be considered while designing a power plant :

1. Availability of cooling water (if cooling towers are used the possibility of adequate make up water).
2. Availability of fuel (water, rail or pipe connection to the fuel source, and the cost of fuel transport).
3. Distance from the centre of gravity of load demand.
4. Cost of land including space for extension, maintenance, workshop and storage yard.
5. Character of soil.
6. Main wind direction and water current in cooling water source (sea, lake or river) in order to minimize air and water pollution, and other ecological considerations.
7. With coal fired stations, disposal of ash.
8. If the plant is erected far from a town, accommodation for staff.

9. Rail and road connections.
10. Security considerations.

Que 1.28. **How can a power plant be designed economically ?**

Answer

1. While planning a power plant, first the power output to be installed is determined from the estimated maximum demand, anticipated growth of demand and reserve capacity needed.
2. After determining the installed capacity, the size and number of generating units are decided according to the load curve or load duration curve.
3. The variable load problem affects power plant design and operation as well as the cost of generation.
4. Due to variable load on the plant, the equipment cannot operate at the designed load points.
5. In order to follow the variable load curve very closely, the total plant capacity has to be usually subdivided into several power units of different sizes.
6. If more units of smaller size are selected than a few units of bigger size, then the total plant capacity would more nearly coincide with the variable load curve.
7. The size and number of generating units should be so chosen that each unit operates on about full load or the load at which it gives the maximum efficiency.
8. The load duration curve helps to decide the size of units to supply the base, intermediate and peak loads.
9. The peak load unit / plant should be of smaller capacity to reduce the cost of generation. Some units must be of unequal capacities to fit the load curve closely. However, identical units result in saving in the fixed cost.
10. In a power plant with many generating units, there must be some spinning reserve in order to maintain the continuity of service.
11. Spinning reserve is that reserve generating capacity which is connected to the bus and is ready to take the load.

☺☺☺

Nuclear Energy

CONTENTS

This is the subtitle of PDF, Use long text here.

PART-1

Fundamental Forces in the Universe, Quantum Mechanics Relevant for Nuclear Physics.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. What are the various fundamental forces present in nature ?

Answer

Various fundamental forces present in nature are as follows :

i. **Gravitational Force :** It is the force of mutual attraction between any two objects by virtue of their masses. It is a universal force as every object experiences this force due to every other object in the universe.

ii. **Electromagnetic Force :** It is the force between charged particles. Charges at rest have electric attraction (between unlike charges) and repulsion (between like charges). Charges in motion produce magnetic force. Together they are called electromagnetic force.

iii. **Strong Nuclear Force :** It is the attractive force between protons and neutrons in a nucleus. It is charge-independent and acts equally between a proton and a proton, a neutron and a neutron, and a proton and a neutron.

iv. **Weak Nuclear Force :** This force appears only in certain nuclear processes such as the β-decay of a nucleus. In β-decay, the nucleus emits an electron and an uncharged particle called neutrino.

Que 2.2. What do you understand by quantum mechanics relevant for nuclear physics ?

Answer

1. Nuclear physics is about the physical nucleus of an atom.
2. So when we are doing quantum mechanics on nuclear physics, it means that we are dealing with a mechanisms which affects the nucleus of an atom, such as protons, neutrons, the strong force that keeps the nucleus together, and the other forces that cause nuclear radiation.

Que 2.3. What do you understand by thermal neutron ? Also explain the properties of neutrons.

Answer

A. **Thermal Neutron :** Thermal neutron is a free neutron that has an average energy of motion corresponding to the average energy of the particles of the ambient materials.

B. **Properties of Neutrons :**

1. Neutrons are fundamental constituents of a nucleus. Inside a nucleus, neutrons stay forever but as a projected particle outside it, it exists for a short time only.
2. In nuclei of heavier elements, the number of neutrons is greater than the number of protons. It is this abundance of neutrons which makes the elements stable.
3. Since neutrons are uncharged particles, therefore these are neither affected by external magnetic or electric fields nor by the presence of protons when they enter or penetrate the nucleus.
4. Depending upon their speed, neutrons are put in two categories :
   i. Fast neutrons, and
   ii. Slow neutrons.
5. Both are fully capable of penetrating a nucleus and causing artificial disintegration in the nucleus.

PART-2

Nuclear Forces, Energy Scales and Structure.

CONCEPT OUTLINE

Nuclear Force : These are the forces which act between two or more nucleons. They bind protons and neutrons into atomic nuclei.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.4. Explain the properties of nuclear forces.

Answer

Properties of nuclear forces are as follows :

1. Nuclear forces are ordinarily attractive. When the distance between two nucleons is 10^{-14} m which is equal to the size of a nucleus, the nuclear force comes into play as an attractive force.

This is the subtitle of PDF, Use long text here.

2. Nuclear forces are charge independent. The nuclear force between two neutrons is the same as that between two protons or between a proton and a neutron.
3. Nuclear forces are short range forces.
4. Nuclear forces are spin dependent. The force between two nucleons having parallel spins is stronger than the force existing between two nucleons having anti parallel spins.
5. Nuclear forces show saturation properties. A nucleon can interact only with those nucleons which are its nearest neighbours.

Que 2.5. **Discuss in brief about structure of nucleus.**

Answer

1. The atomic nucleus is present in the center of the atom. It consists of protons and neutrons collectively known as nucleus.
2. The number of protons and neutrons in the atom define what type of atom or element it is.
3. The structure of the atomic nucleus gives us lots of information about the element it represents. The number of protons inside the nucleus gives us the atomic number. The protons have a positive charge.
4. In order for the atom to have a neutral charge, the electrons need to balance it out with their negative charge. Therefore, in a neutral atom there are just as many protons as electrons.
5. So, if we know the atomic number and know the charge of the atom then the number of electrons is easy to find.

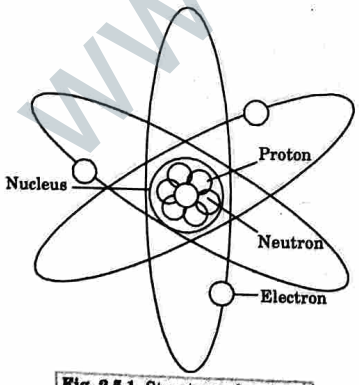


Fig. 2.5.1. Structure of nucleus.

PART-3

Nuclear Binding Energy Systematics, Reactions and Decays.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.6. **What do you mean by binding energy ? What are the total binding energy and binding energy per nucleon for the $_6C^{12}$ nucleus ?**

Answer

A. Binding Energy :

1. Binding energy is defined as the energy required to overcome the binding forces of nucleus.
2. When the nucleus of an atom is formed then the nucleons come closer to each other and this distance between the two nucleons is of the order of nearly 10^{-12} mm.
3. At the moment of combination there is a release of energy which is known as binding energy.

B. Numerical :

1. The atomic weight of $_6C^{12}$ = 12.000 amu
2. The predicted mass of $_6C^{12}$ is given as :
   Mass of 6 protons = 1.00759 × 6 = 6.04554 amu
   Mass of 6 neutrons = 1.00898 × 6 = 6.05388 amu
   Mass of 6 electrons = 0.00055 × 6 = 0.00330 amu
   Total = 12.10272 amu
   Isotopic mass = 12.00000 amu
3. Therefore, Mass defect = 12.10272 – 12.00000
   = 0.10272 amu
4. Energy equivalent of 1 amu
   = 933.75 MeV
5. Therefore, total binding energy
   = 933.75 × 0.10272 = 95.91 MeV
6. Binding energy per nucleon,
   $= \frac{95.91}{12}$
   = 7.99 MeV

Que 2.7. **Draw the binding energy curve showing variation of binding energy per nucleon with mass number. With the help of this, explain the phenomenon of nuclear fusion and fission.**

AKTU 2019-20, Marks 10

Answer

A. Binding Energy Curve :

1. The graphical relationship between binding energy per nucleon and mass number is called binding energy curve.
2. Fig. 2.7.1 shows binding energy curve. The average binding energy per nucleon is plotted against mass number for naturally occurring nuclei.
3. Following are the special features of binding energy curve.
   - i. The binding energy per nucleon of very light nuclides such as $^{2}_{1}H$ is very small.
   - ii. Initially, there is a steep rise in curve. This indicates a rapid rise in the value of binding energy per nucleon.
   - iii. Between mass number 4 and 20, the curve shows cyclic recurrence of peaks corresponding to $^{4}_{2}He$, $^{8}_{2}Be$, $^{12}_{6}C$, $^{16}_{8}O$ and $^{20}_{10}Ne$. This shows that the binding energy per nucleon of these nuclides is greater than those of their immediate neighbours.

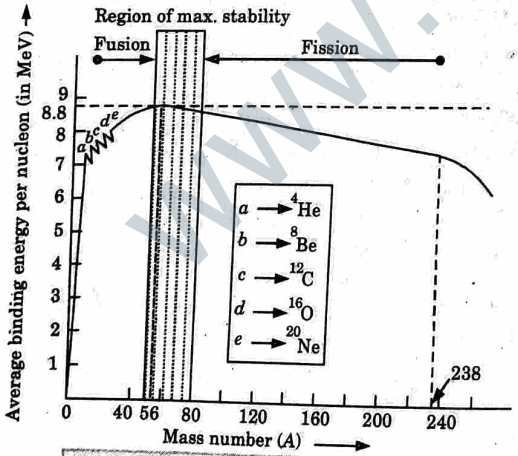


Fig. 2.7.1. Plot of binding energy per nucleon as a function of mass number.

- iv. After mass number 20, there is a gradual increase in binding energy per nucleon. The maximum value is reached at $A = 56$. This value is 8.8 MeV. Clearly, the iron nucleus ($^{56}_{26}Fe$) is the most stable.
- v. The binding energy per nucleon of nuclides having mass numbers ranging from 40 to 120 is close to the maximum value. So, these elements are highly stable and non-radioactive.
- vi. Beyond $A = 120$, the value decreases and falls to 7.6 MeV for uranium. This decrease is primarily due to repulsion among protons whose number increases in heavy nuclides.
- vii. Beyond $A = 238$, the binding energy per nucleon shows a rapid decrease with increase in mass number.
- viii. The fact that the binding energy curve droops at both high and low mass numbers has very important practical consequences.

B. Phenomenon of Nuclear Fusion and Fission :

1. The drooping of the binding energy curve at high mass numbers tells us that nucleons are more tightly bound when they are assembled into two middle mass nuclei rather that into a single high mass nucleus. This is known as nuclear fission.
2. The drooping of the binding energy curve at low mass numbers, on the other hand, tells us that energy will be released if two nuclei of small mass numbers combine to form a single middle mass nucleus. This process, the reverse of fission is called nuclear fusion.

Que 2.8. **Write a short note on chain reaction.**

Answer

1. A chain reaction is that process in which the number of neutrons keeps on multiplying rapidly during fission till whole of the fissionable material is disintegrated.
2. If at least one fission neutron becomes available for causing fission of another nucleus then the chain reaction will become self-sustaining or self-propagating.
3. This condition can be conveniently expressed in the term of multiplication factor or reproduction factor of the system which may be defined as :

$$K = \frac{\text{Number of neutrons in any particular generation}}{\text{Number of neutrons in the preceeding generation}}$$

4. If $K > 1$, chain reaction will continue and if $K < 1$, chain reaction cannot be maintained.

This is the subtitle of PDF, Use long text here.

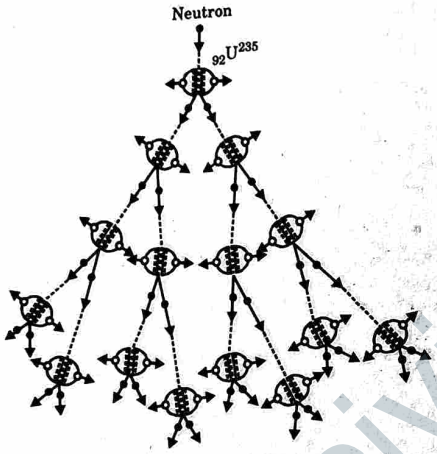


Fig. 2.8.1. Chain reaction.

Que 2.9. **Write a short note on radioactivity.**

Answer

1. Most of the naturally occurring isotopes are stable. But those isotopes which are not stable are known as radioactive isotopes.
2. A continuously undergoing spontaneous (*i.e.*, without outside help) disintegration of radioactive isotopes is called radioactivity.
3. This is accompanied by the emission of one or more smaller particles from the parent nucleus.
4. The resulting nucleus is known as daughter nucleus.
5. The parent nucleus is said to decay into the daughter nucleus.
6. The daughter nucleus may or may not be stable, and several successive decays may occur until a stable isotope is formed.
7. Radioactivity may be natural or artificial.

Que 2.10. **Show that radioactive decay follows exponential law.**

Answer

1. We know that the small amount of disintegration of the isotope in a small period is directly proportional to the total number of radioactive nuclei and proportionality constant.

2. Let, N = Number of radioactive nuclei present at any time t,
   N_0 = Initial number of such nuclei, and
   λ = Proportionality constant.
3. This can be stated in the form of equation as follows :

$$\Delta N = -\lambda N \Delta t \quad \text{...(2.10.1)}$$

$$\frac{dN}{dt} = -\lambda N \quad \text{...(2.10.2)}$$

The negative sign represents that during disintegration the number of the nuclei is decreasing.

4. Integrating the eq. (2.10.2) within the proper limits, we get

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt \quad \text{...(2.10.3)}$$

or $\log_e N - \log_e N_0 = -\lambda t$ or $\log_e \frac{N}{N_0} = -\lambda t$

or $\frac{N}{N_0} = e^{-\lambda t}$ or $N = N_0 e^{-\lambda t}$

$$\frac{dN}{dt} = -\lambda N = -\lambda N_0 e^{-\lambda t} \quad \text{...(2.10.4)}$$

The eqn. (2.10.4) represents that the decay scheme follows the exponential law.

Que 2.11. **What are the various types of radioactive decay ?**

Answer

Various types of radioactive decay are as follows :

a. Alpha (α) Decay :

1. α particles are helium nuclei, each consisting of two protons and two neutrons and are commonly emitted by the heavier radioactive nuclei.
2. The decay of Pu^{239} into fissionable U^{235} and α (He^4) particles is an example of α-decay.

$$_{94}Pu^{239} \xrightarrow{\alpha} {}_{92}U^{235} + {}_{2}He^{4}$$

b. Beta (β) Decay :

1. It is commonly accompanied by the emission of neutrino (Δ) and γ radiation.
2. An example of β decay,

$$_{82}Pu^{214} \xrightarrow{\beta} {}_{83}Bi^{214} + {}_{-1}e^{0} + \Delta$$

3. The penetrating power of β particles is small compared to γ rays, however, it is larger than that of α particles.

c. Gamma (γ) Decay :

1. γ particles are electromagnetic radiation of extremely short wavelength and very high frequency resulting in high energy.
2. γ rays originate from the nucleus while X-rays from the atom. γ wavelength are on an average, about one tenth those of X-rays, though energy ranges overlap somewhat.
3. There is no alternation of atomic or mass number due to γ decay.

d. Positron Decay :

1. Positron decay is caused when the radioactive nucleus contains an excess of protons.
2. An example of this is the decay of $_7Ni^{23}$ into $_6C^{13}$ which is shown below,

$$_7Ni^{13} \longrightarrow {}_6C^{13} + {}_{+1}e^0$$

Que 2.12. Explain briefly the following terms related to radioactive decay :
a. Activity,
b. Half life, and
c. Average (mean) life.

Answer

a. Activity :

1. Activity is defined as the intensity of emitted radiation.
2. This is directly dependent on the rate of disintegration of the element.
3. Let, A = Activity at time t,
   A_1 = Initial activity, and
   k = Detection coefficient.

$$\therefore \quad A = k\left(-\frac{dN}{dt}\right) = k\lambda N$$
$$= k\lambda N_o e^{-\lambda t}$$
$$A = A_1 e^{-\lambda t}$$

b. Half Life :

1. Half life represents the rate of decay of the radioactive isotopes.
2. The half life is the time required for half of the parent nuclei to decay or to disintegrate.
3. We know that, $N = N_o e^{-\lambda t}$ ...(2.12.1)
4. Putting $N = \frac{N_0}{2}$ and $t = t_{1/2}$ in eq. (2.12.1), we get

$$\frac{N_0}{2} = N_o e^{-\lambda t_{1/2}}$$

5. Therefore, $e^{-\lambda t_{1/2}} = 1/2$

$$\lambda t_{1/2} = \log_e 2 = 0.693$$

$$t_{1/2} = \frac{0.693}{\lambda} \quad ...(2.12.2)$$

c. Average (Mean) Life :

1. Average (mean) life indicates the average of total time for which the radioactive nuclei has disintegrated for several half lives. Hence this is greater than half life.
2. This is obtained by taking the sum of the decay time of the radioactive nuclei and then it is divided by the initial number of nuclei.
3. If T is the time of average life, then

$$T = \frac{-\int_0^\infty t dN}{N_0} = \frac{\lambda N_0 \int_0^\infty t\, e^{-\lambda t} dt}{N_0}$$

4. On solving, $T = \left[-te^{-\lambda t} - \frac{e^{-\lambda t}}{\lambda}\right]_0^\infty$

$$T = \frac{1}{\lambda} \quad ...(2.12.3)$$

5. On dividing eq. (2.12.3) by eq. (2.12.2), we get $\frac{T}{t_{1/2}} = 1.445$
6. So, it is clear that mean life is 1.445 times greater than half life.

PART-4

Nuclear Fusion, Nuclear Fission and Fission Reactor Physics.

CONCEPT OUTLINE

Fusion : In fusion, two or more light nuclei fuse to form heavier nuclei.
Fission : In fission, a heavy nucleus is split into two or more lighter nuclei.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.13. What is nuclear fusion ? How does it differ from nuclear fission ? **AKTU 2019-20, Marks 10**

Answer

A. Nuclear Fusion : It is a reaction in which two or more atomic nuclei are combined to form one or more different atomic nuclei and subatomic particles (neutrons or protons).

B. Comparison of Nuclear Fission and Nuclear Fusion Processes :

S. No.	Nuclear Fission	Nuclear Fusion
1.	A heavy nucleus breaks up to form two lighter nuclei.	Two nuclei combine to form a heavy nucleus.
2.	It involves a chain reaction.	Chain reaction is not involved.
3.	Nuclear reaction residual problem is high.	Residual problem is much less.
4.	Amount of radioactive material in a fission reactor is high.	Amount of radioactive material is less.
5.	Because of higher radioactive material, health hazard is high in case of accidents.	Because of lesser radioactive material, health hazard is much less.
6.	We have proper mechanisms to control fission reaction for generating electricity.	Proper mechanisms to control fusion reaction are yet to be developed.
7.	Raw material is not easily available and is costly.	Raw material is comparatively cheap and easily available.
8.	Disposal of nuclear waste is a great environment problem.	Disposal of nuclear waste is not involved.

Que 2.14. Write short note on nuclear fission.

Answer

1. Nuclear fission is defined as a type of nuclear disintegration in which heavy nucleus splits up into two nuclei of nearly comparable masses with liberation of energy.
2. The fission is accompanied by the release of three neutrons and radiation energy in the form of γ-rays.
3. The reaction is represented as,

$$ {}_0^1n + {}_{92}^{238}U \rightarrow [{}_{92}^{236}U] \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3\,{}_0^1n + \gamma $$

4. The diagrammatic sketch is given in Fig. 2.14.1. A neutron strikes the ^{235}U nucleus and in the process two nuclides ^{141}Ba and ^{92}Kr are formed with the release of 3 neutrons.

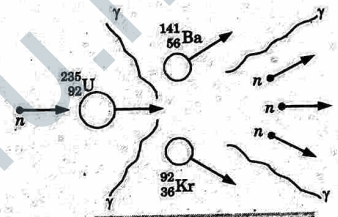


Fig. 2.14.1. Nuclear fission.

5. The wavy lines indicate the energy released in the form of γ radiations. A slow neutron is used to cause fission.
6. Further whereas one neutron is lost in the process to produce fission, three neutrons are produced as a product of the fission. This fact has tremendous significance in the construction of nuclear bomb.

Que 2.15. What do you mean by nuclear reactor ? Explain its different parts.

Answer

A. Nuclear Reactor :

1. The nuclear reactor may be regarded as a substitute for the boiler fire box of steam power plant or combustion chamber of gas turbine plant.
2. The heat produced in the nuclear reactor is by fission process whereas in steam and gas power plants, the heat is produced by combustion of fuel.
3. The other cycle of operation and components required is the same either as steam plant or a gas turbine plant.
4. The steam or gas may be the working fluid in nuclear power plant.

B. Different Parts of Nuclear Reactor :

i. Fuel Element :

1. The nuclear fuels which are generally used in reactors are $_{92}U^{235}$, $_{94}Pu^{239}$ and $_{92}U^{233}$.
2. Out of the three, the $_{92}U^{235}$ is only naturally available upto 0.7 % in the uranium are 239 and the remaining is $_{92}U^{238}$.
3. The other two fuels $_{94}Pu^{239}$ and $_{92}U^{233}$ are the byproduct and formed in the nuclear reactor during fissioning process from $_{92}U^{238}$ and $_{90}Th^{232}$ due to absorption of neutron without fission.

4. The selection of the shape of the fuels and their locations in the reactor are made keeping in view of uniform heat production within the reactor.
5. The fuel elements are designed taking into account the heat transfer, corrosion and structural strength.

ii. Moderator :

1. It is a material used to slow down the neutrons from high kinetic energy (1 MeV or 13200 km/s) to low kinetic energy (0.25 eV or 2200 m/s) in a fraction of a second.
2. Further, a moderator is used to increase the probability of reaction and to maintain the chain reaction due to slow neutrons.
3. The slowing down of the neutrons is effectively done by the light elements such as H_2, D_2, N_2, O_2, C and Be.

iii. Reflector :

1. In order to keep the critical size of the reactor and hence the amount of fissionable material as small as possible, it is important to conserve neutrons.
2. This is possible by surrounding the reactor core with a material which reflects escaping neutrons back into the core. This material is called reflector.
3. The required properties of a good reflector are low absorption and high reflection for neutrons, high resistance to oxidation and irradiation as well as high radiation stability.
4. Many times the materials used as moderator is also used as reflector.
5. The H_2O, D_2O and carbon are also used as reflector.

iv. Coolant :

1. The main purpose of the coolant in the reactor is to transfer the heat produced in the reactor and to keep the fuel assembly at a safe temperature to avoid their melting and destruction.
2. The same heat carried by the coolant is used in the heat exchanger for further utilization in the power generation either generating steam or using hot gas.
3. The water, heavy water, gas (He, CO_2), a metal in liquid form (Na) and organic liquids are used as coolant.

v. Control Rods :

1. The control system controls the rate of energy generated. It starts, increase, decrease and stops the reaction.
2. These rods may be shaped like the fuel rods themselves and are interspread throughout the core.
3. Instead of containing fuel, they contain neutron absorber such as boron, cadmium or indium.

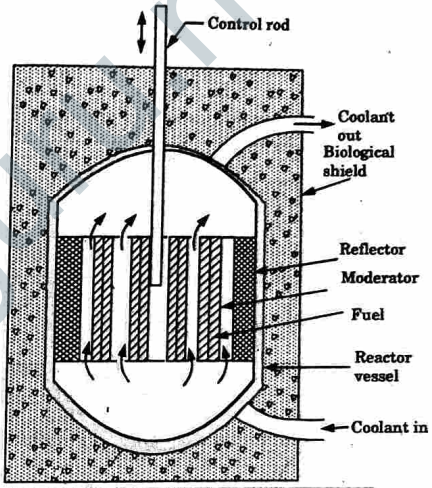


Fig. 2.15.1. Principal parts of a nuclear reactor.

vi. Biological Shield :

1. The intensity of radiations and radioactive fragments from the reactor core is too high for the human body to tolerate.
2. Therefore, it is necessary to surround the reactor with shielding material to prevent damage of human body due to radiation.

vii. Reactor Vessel :

1. The reactor vessel encloses the reactor core, reflector and shield. It also provides coolant inlet and outlet passages.
2. The reactor vessel has to withstand the pressure at 200 bar or above.
3. The reactor core (fuel and moderator assembly) is generally placed at the bottom of the vessel.

PART-5

Nuclear Fission Reactor Design.

This is the subtitle of PDF, Use long text here.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.16. **With the help of neat diagram, explain the working of a boiling water reactor (BWR).**

Answer

1. In a boiling water reactor enrich fuel is used.
2. The arrangement of BWR is simpler than the pressurized water reactor (PWR).
3. The plant can be safely operated using natural convection within the core or forced circulation.
4. The pressure in the forced circulation is maintained constant irrespective of the load.
5. In case of part load operation of the turbine some steam is by-passed.
6. In BWR, the steam flowing to the turbine is produced directly in the reactor core.
7. Steam is separated and dried by mechanical devices located in the upper part of the pressure vessel assembly.
8. The dried steam is sent directly to the high pressure turbine thus eliminating the need for steam generators.
9. The coolant thus serves the triple function of coolant, moderator and working fluid.

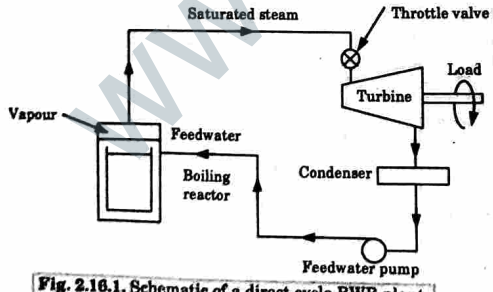


Fig. 2.16.1. Schematic of a direct cycle BWR plant.

10. Since the coolant boils in the reactor itself, its pressure is much less than that in a PWR and it is maintained at about 70 bar with steam temperature around 285 °C.

11. An increase in the boiling rate displaces water (moderator) to thermalize neutrons and hence, reduces the reactor power level.
12. The saturated liquid that separates from the vapour at the top of the reactor in a steam separator flows downward either internally within the reactor or externally outside the reactor and mixes with the return condensate.

Que 2.17. **With a neat sketch, explain pressurized water reactor (PWR) highlighting its merits and demerits.**

AKTU 2019-20, Marks 10

Answer

A. Pressurized Water Reactor (PWR):

1. A pressurized water reactor is a light water cooled and moderated thermal reactor having an unusual core design, using both natural and highly enriched fuel.
2. The principal parts of PWR are :
   a. Pressure vessel,
   b. Reactor thermal shield,
   c. Fuel elements,
   d. Control rods,
   e. Reactor containment, and
   f. Reactor pressurizer.
3. In PWR, the primary circuit passes through the fuel core and is radioactive.
4. This primary circuit then produces steam in a secondary circuit which consists of heat exchanger or the boiler and the turbine.

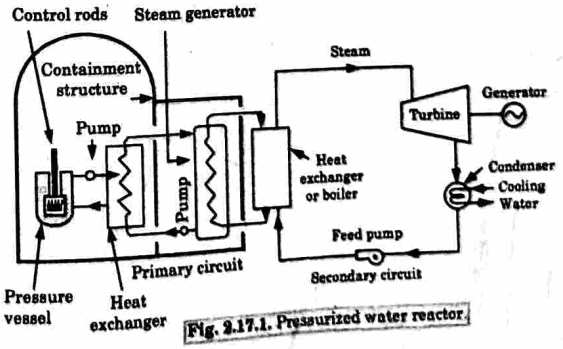


Fig. 2.17.1. Pressurized water reactor.

5. As the steam in the turbine is not radioactive and need not be shielded.
6. The pressure in the primary circuit should be high so that the boiling of water takes place at high pressure.
7. A pressuring tank keeps the water at about 100 kgf/cm^2 so that it will not boil.
8. Electric heating coil in the pressurizer boil some of the water to form steam that collects in the dome.
9. The pressure of the dome goes on increasing as more steam is forced into it.
10. By providing the cooling coils or spraying water on the steam the pressure may be reduced.
11. Water acts both as coolant as well as moderator.
12. A pressurized water reactor can produce only saturated steam. By providing a separate furnace the steam formed from the reactor could be superheated.

B. Merits of PWR :

1. Water used in reactor is cheap and easily available.
2. The reactor is compact and power density is high.
3. Fission products remain contained in the reactor and are not circulated.
4. A small number of control rods are required.

C. Demerits of PWR :

1. Capital cost is as high primary circuit requires strong pressure vessel.
2. In the secondary circuit the thermodynamic efficiency of this plant is quite low.
3. Fuel suffers radiation damage and, therefore its reprocessing is difficult.
4. Severe corrosion problems.

Que 2.18. Describe pressurized heavy water reactor (PHWR).

Answer

1. A pressurized heavy water reactor (PHWR) is a nuclear power reactor, commonly using unenriched natural uranium as its fuel that uses heavy water (deuterium oxide D_2O) as its coolant and moderator.
2. The heavy water coolant is kept under pressure, allowing it to be heated to higher temperatures without boiling much as in a typical pressurized water reactor.
3. While heavy water is significantly more expensive than ordinary light water, it yields greatly enhanced neutron economy, allowing the reactor to operate without fuel enrichment facilities and generally enhancing the ability of the reactor to efficiently make use of alternate fuel cycles.

4. The CANDU reactor is the first and most widely used heavy water reactor.

PART-6

Safety, Operation and Fuel Cycles.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.19. Explain nuclear fuel cycle with block diagram.

Answer

1. The nuclear fuel cycle is the series of industrial processes which involves the production of electricity from uranium in nuclear power reactors.
2. Fuel removed from a reactor, after it has reached the end of its useful life, can be reprocessed so that most is recycled for new fuel.

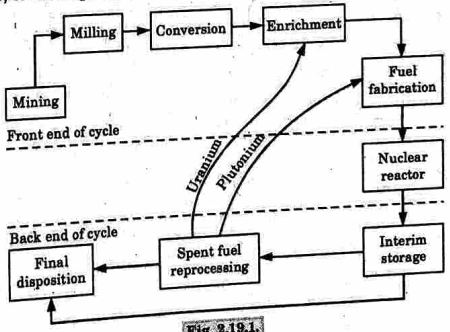


Fig. 2.19.1.

3. The various activities associated with the production of electricity from nuclear reactions are referred to collectively as the nuclear fuel cycle.
4. The nuclear fuel cycle starts with the mining of uranium and ends with the disposal of nuclear waste. With the reprocessing of used fuel as an option for nuclear energy, the stages form a true cycle.

5. To prepare uranium for use in a nuclear reactor, it undergoes the steps of mining and milling, conversion, enrichment and fuel fabrication. These steps make up the front end of the nuclear fuel cycle.
6. After uranium has spent about three years in a reactor to produce electricity, the used fuel may undergo a further series of steps including temporary storage, reprocessing, and recycling before wastes are disposed. Collectively these steps are known as the back end of the fuel cycle.

Que 2.20. Discuss some safety measures for nuclear power plants.

Answer

Safety measures for nuclear power plants are as follows :

1. A nuclear power plant should be constructed away from human habitation. An exclusion zone of 106 km radius around the plant should be provided where no public habitation is permitted.
2. The materials to be used for the construction of a nuclear power plant should be of required standards.
3. Waste water from nuclear power plant should be purified.
4. The nuclear power plant must be provided with such a safety system which should safely shut down the plant as and when necessity arises.
5. There must be periodic checks to ensure that radioactivity does not exceed the permissible value in the environment.
6. While disposing off the wastes from the nuclear plants it should be ensured that there is no pollution of water of river or sea where these wastes are disposed.

☺☺☺

UNIT 3

Solar Energy

CONTENTS

This is the subtitle of PDF, Use long text here.

PART-1

Introduction to Solar Energy.

CONCEPT OUTLINE

Solar Cell : Solar cells are energy conversion device which are used to convert sunlight to electricity by the use of the photovoltaic effect.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. Describe solar energy along with its merits and demerits.

Answer

A. Solar Energy :

1. Solar energy is a clean, cheap and abundantly available renewable energy and it is also the most important of the non-conventional sources of energy because it is non-polluting and therefore helps in decreasing the green house effect.
2. Solar energy can be used :
   i. By direct conversion to a fuel by photosynthesis.
   ii. By direct conversion to electricity by photovoltaic.
   iii. By conversion to electricity via thermo-electric power system.
3. The sun releases the enormous amount of energy due to continuous fusion reaction taking place inside the sun.
4. The sun sends out the energy in the form of radiations at the rate of 3.7×10^{20} MW.
5. However, the energy intercepted by the earth is about 1.85×10^{11} MW.
6. This energy available is several times more than all the energy produced and consumed in the world.

B. Merits of Solar Energy :

1. Noiseless operation.
2. Occupies less space on floor as there is no need of storage vessels.
3. Cheaper initial cost and no need of containers to store the fuel.

C. Demerits of Solar Energy :

1. Solar equipments fail to work in nights, cloudy days or rainy season.

2. Large space is required for the collection of solar energy at a useful rate.
3. High initial cost for solar panels.

Que 3.2. Explain with a neat sketch, working of a solar cell.

AKTU 2019-20, Marks 10

Answer

1. When light reaches the *p-n* junction, the light photons can easily enter in the junction, through very thin *p*-type layer.
2. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs.
3. The incident light breaks the thermal equilibrium condition of the junction.
4. The free electrons in the depletion region can quickly come to the *n*-type side of the junction. Similarly, the holes in the depletion can quickly come to the *p*-type side of the junction.
5. Once, the newly created free electrons come to the *n*-type side cannot further cross the junction because of barrier potential of the junction. Similarly, the newly created holes once come to the *p*-type side cannot further cross the junction because of same barrier potential of the junction.
6. As the concentration of electrons becomes higher in one side, *i.e.*, *n*-type side of the junction and concentration of holes becomes more in another side, *i.e.*, the *p*-type side of the junction, the *p-n* junction will behave like a small battery cell.
7. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

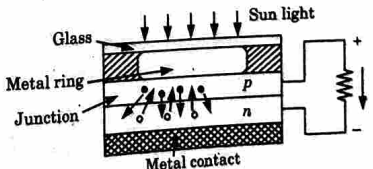


Fig. 3.2.1.

PART-2

Fundamental of Solar Radiation and its Measurement Aspects.

CONCEPT OUTLINE

Solar Constant : The rate at which solar radiation strikes at the top of the atmosphere is called the solar constant.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.3. **Write a short note on solar radiation.**

Answer

1. Solar radiation is the electromagnetic radiation emitted by the sun. This radiation can be converted into useful forms of energy, such as heat and electricity by the different types of technologies.
2. The solar radiations received by the earth's surface vary with the location.
3. However radiation received outside the earth's atmosphere is different than what we receive on the earth surface because of absorption, reflection, scattering and attenuation by particulates and clouds present in the atmosphere.
4. The solar radiation is grouped in the following two categories :

a. Extraterrestrial Solar Radiation :

1. Extraterrestrial radiation is the measure of solar radiation that would be received in the absence of atmosphere.

b. Terrestrial Solar Radiation :

1. The radiation we receive on the earth surface is called terrestrial radiation and is nearly 70 % of extraterrestrial radiation.
2. Solar radiation passes through the earth's atmosphere and is subjected to scattering and atmospheric absorption and a part of scattered radiations are reflected back into space.

Que 3.4. **Define the terms used in solar radiation.**

Answer

Terms used in solar radiations are as follows :

i. **Beam Radiation (I_b) :** Solar radiation received on the earth's surface without change in direction is known as beam or direct radiation.

ii. **Diffuse Radiation (I_d) :** The radiation received on a terrestrial surface (scattered by aerosols and dust) from all parts of the sky dome is known as diffuse radiation.

iii. **Total Radiation (I_T) :** The sum of beam and diffuse radiation intercepted at the earth's surface per unit area of location is known as total radiation and it is also known as insolation. The radiations received by a collector surface are always global radiations.

iv. **Air Mass (m_a) :** It is the ratio of the path length of beam radiation through the atmosphere, to the length of path when sun is at over head or zenith.

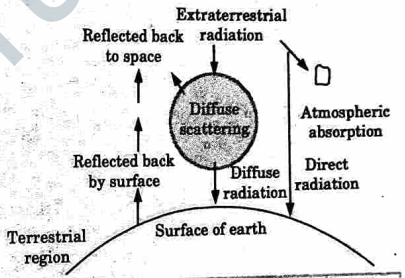


Fig. 3.4.1. Direct diffuse and total solar radiation.

Que 3.5. **Explain the difference between direct radiation and diffuse radiation.** **AKTU 2019-20, Marks 10**

Answer

S. No.	Direct Radiation	Diffuse Radiation
1.	Solar radiation received on the earth's surface without change in direction is known as direct radiation.	The radiation received on a terrestrial surface (scattered by aerosols and dust) from all parts of the sky dome is known as diffuse radiation.
2.	It has a unique path.	It does not have a unique path.
3.	Direct solar radiation is generally most intense at any one spot on the surface of the earth at solar noon.	It does not happen in diffuse radiation.
4.	It has the least amount of the atmosphere to travel through.	It has the more amount of the atmosphere to travel through.

Que 3.6. **Explain solar radiation geometry.**

Answer

Various angles related to solar radiation geometry are as follows :

a. Incident Angle (θ) : It is defined as the angle between the incident beam radiation and the normal to a plane surface.

b. Latitude Angle (ϕ) :

1. The latitude of a place is the angle subtended by the radial line joining the place to the centre of the earth, with the projection of the line on the equatorial plane.
2. The latitude is taken as positive for any location towards the northern hemisphere and negative towards the southern hemisphere *i.e.*, the latitude at equator is 0° while at north and south poles are + 90° and – 90° respectively.

c. Declination Angle (δ) :

1. The declination is the angle made by the line joining the centres of the sun and the earth with its projection on the equatorial plane.
2. The declination angle varies from a maximum value of + 23.5° on June 21 to a minimum of – 23.5° on December 21.

d. Hour Angle (ω) :

1. It is the angle through which the earth must be rotated to bring the meridian of a point directly in line with the sun's ray.
2. In other words, it is the angular displacement of the sun, east or west of the local meridian, due to the rotation of the earth on its axis at an angle of 15° per hour.

e. Altitude Angle (α) : It is a vertical angle between the projection of the sun's rays on the horizontal plane and the direction of the sun's rays.

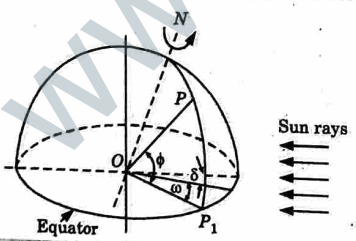


Fig. 3.6.1. Latitude ϕ, hour angle ω and sun's declination δ.

f. Zenith Angle (θ_z) : It is the vertical angle between the sun's rays and line perpendicular to the horizontal plane through the point.

g. Surface Azimuth Angle (γ) : It is the angle in the horizontal plane between the line due south and the horizontal projection of the normal to the inclined plane surface.

h. Slope (β) :

1. It is the angle between the plane surface, under consideration, and with the horizontal.
2. It is taken to be positive for surface sloping towards south and negative for surfaces sloping towards north.

i. Solar Azimuth Angle (γ_s) :

1. It is the angle in a horizontal plane, between the line due south and the projection of beam radiation on the horizontal plane.
2. Thus it gives the direction of the shadow cast in the horizontal plane by a vertical rod.

Que 3.7. What are the devices used for measuring the solar radiations ? Explain each with their construction and working.

Answer

Various devices used for measuring the solar radiations are as follows :

A. Pyranometer : It is a device used for measuring global or diffuse radiations.

a. Construction : It consists of following components :

i. Black Surface : This receives the beam as well as diffuse radiations which rises heat.

ii. Glass Dome : It prevents the loss of radiation received by the black surface.

iii. Thermopile : It is a temperature sensor and consists of a number of thermocouples connected in series to increase the sensitivity.

iv. Supporting Stand : It keeps the black surface in a proper position.

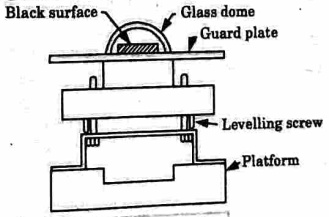


Fig. 3.7.1. Pyranometer.

b. Working :

1. The pyranometer is kept exposed to the sun and it starts receiving the radiations.
2. Due to the absorption of the radiation, the surface temperature starts rising and the increase in temperature of the absorbing surface is detected by the thermopile.

3. The thermopile generates a thermo-emf which is proportional to the radiations absorbed and this thermo-emf is calibrated in terms of the received radiations. This measures the global radiations.

B. Pyrheliometer : It is a device used for measuring the beam or direct radiations.

a. Construction : It consists of following components :

i. **Receiver :** It is in the shape of a hollow tube with reflecting surface inside.

ii. **Absorber Plate :** It consists of a blackened surface and it is placed at the bottom of the tube.

iii. **Thermopile :** It is a sensing element of temperature consisting of a group of thermopiles.

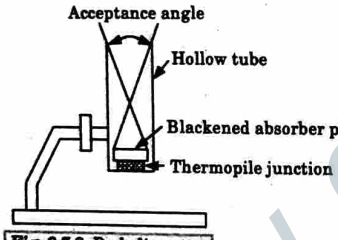


Fig. 3.7.2. Pyrheliometer.

b. Working :

1. The hollow receiver tube can be tilted about an axis perpendicular to its length.
2. Thus, the tube can be made to face the sun's radiation, thereby receiving only the beam radiation and no diffuse radiation can enter the tube.
3. When the radiation falls on the absorber plate, it absorbs the radiation and it gets heat up, and thereby temperature rises.
4. The rise in temperature is measured by measuring the thermo-emf of the thermopile.

C. Sunshine Recorder : It is a device used to measure the hours of bright sunshine in a day.

a. Construction : It consists of a glass sphere installed in a section of spherical metal bowl, having grooves for holding a recorder card strip and the glass sphere for adjusting the focus of sun rays to a point on the card strip.

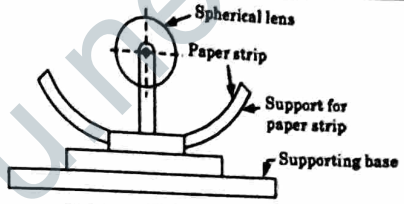


Fig. 3.7.3. Sunshine recorder.

b. Working :

1. Sun's beam is focused to a point by a spherical glass, which acts as a convex lens and graduated paper strip is placed at the focal point.
2. Due to the heating effect of the focused beam, a burn mark is produced on the paper and the graduation on the paper is done as per the hours of the day.

Que 3.8. Write short note on :

a. Solar radiance, and
b. Solar insolation.

Answer

a. Solar Radiance :

1. The solar radiance is an instantaneous power density in units of kW/m^2.
2. The solar radiance is strongly dependant on location and local weather.
3. Solar radiance measurements consist of global and/or direct radiation measurements taken periodically throughout the day.
4. The measurements are taken using either a pyranometer or a pyrheliometer.

b. Solar Insolation :

1. The solar insolation is the total amount of solar energy received at a particular location during a specified time period, often in units of $kWh/(m^2\ day)$.
2. Solar insolation data is commonly used for simple photovoltaic (PV) system design while solar radiance is used in more complicated PV system.
3. By knowing the insolation levels of a particular region we can determine the size of solar collector that is required and how much energy it can produce.
4. Solar insolation can be measured using sunshine recorders. These sunshine recorders measure the number of hours in the day during which the sunshine is above a certain level.

5. Data collected in this way can be used to determine the solar insolation by comparing the measured number of sunshine hours to those based on calculations and including several correction factors.
6. A final method to estimate solar insolation is cloud cover data taken from existing satellite images.

PART-3

Basic Physics of Semiconductors, Carrier Transport, Generation and Recombination in Semiconductors.

CONCEPT OUTLINE

Semiconductors : The elements whose conductivity lies between metals and insulators. Most frequently used semiconductors in construction of electronic devices are Ge, Si, and GaAs.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.9. Give the classification of semiconductors.

Answer

The semiconductors can be divided into following two types :

a. Intrinsic Semiconductors :

1. An intrinsic semiconductor, also called an undoped semiconductor or *I*-type semiconductor, is a pure semiconductor without any significant dopant species.
2. The number of charge carriers is therefore determined by the properties of the material itself instead of the amount of impurities.
3. The conductivity of intrinsic semiconductors can be due to crystal defects or due to thermal excitation.
4. In an intrinsic semiconductor, the number of electrons in the conduction band is equal to the number of holes in the valence band.

b. Extrinsic Semiconductors :

1. An extrinsic semiconductor is a semiconductor that has been doped, *i.e.*, into which a doping agent has been introduced, giving it different electrical properties than the intrinsic (pure) semiconductor.

2. Doping involves adding dopant atoms to an intrinsic semiconductor which changes the electron and hole carrier concentrations of the semiconductor at thermal equilibrium.
3. The electrical properties of extrinsic semiconductors make them essential components of many electrons devices.
4. Dominant carrier concentrations in an extrinsic semiconductor classify it as either :
   i. *n*-type semiconductor, and
   ii. *p*-type semiconductor.

Que 3.10. What is the difference between intrinsic and extrinsic semiconductor ? **AKTU 2019-20, Marks 10**

Answer

S. No.	Intrinsic Semiconductor	Extrinsic Semiconductor
1.	It is a pure semiconductor with no impurity.	It is an impure semiconductor *i.e.*, a controlled pentavalent or trivalent impurity is added.
2.	The number of free electrons in the conduction band is equal to the number of holes in the valence band.	In an *n*-type semiconductor, free electrons far exceed the holes. In *p*-type semiconductor, it is the reverse.
3.	Its electrical conductivity is low.	Its electrical conductivity is high.
4.	Its electrical conductivity depends on the temperature alone.	Its conductivity depends on the temperature and amount of doping.
5.	It is of no practical use.	It is used in electronic devices.

Que 3.11. Classify semiconductors on the basis of energy band gap with the help of suitable diagram.

Answer

A. Direct Band Gap Semiconductors :

1. In direct band gap semiconductors, an electron in conduction band fall directly to valence band, giving off the energy difference E_g as a photon of light.
2. It cannot undergo change in energy and momentum.

Example : GaAs, GaN etc.

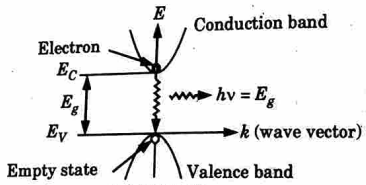


Fig. 3.11.1.

B. Indirect Band Gap Semiconductors :

1. In indirect band gap semiconductors, an electron in conduction band fall indirectly to valence band giving a part of energy to the lattice in the form of heat.
2. It undergoes a change in momentum as well as energy.

Example : Si, Ge etc.

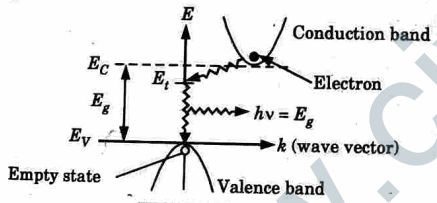


Fig. 3.11.2.

Que 3.12. Explain *n*-type and *p*-type semiconductors.

Answer

A. *n*-type Semiconductors :

1. When a small amount of pentavalent impurity is added to pure semiconductor crystal during the crystal growth, the resulting crystal is called *n*-type extrinsic semiconductor.
2. Fig. 3.12.1 shows the arsenic (As) atom fits in germanium (Ge) crystal in such a way that its four valence electrons form covalent bond with four germanium atom.
3. The fifth electron of arsenic is not bonded and acts as free electron.
4. This electron is available as a carrier of current.
5. This free electron acts as donor whenever required with any other semiconductor.
6. The electrons are the majority carriers while holes are the minority carriers in such cases.

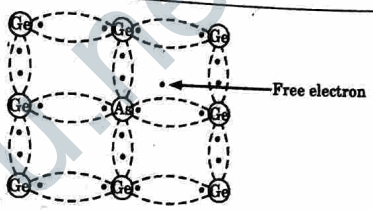


Fig. 3.12.1. Arsenic electron as free electron (donor).

B. *p*-type Semiconductors :

1. When a small amount of trivalent impurity is added to pure crystal during the crystal growth, the resulting crystal is called *p*-type extrinsic semiconductor.
2. Fig. 3.12.2 shows each atom of boron *i.e.*, trivalent impurity is added to pure germanium crystal.

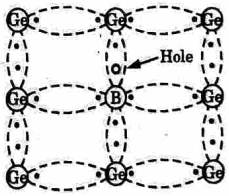


Fig. 3.12.2. Boron hole (acceptor).

3. The three valence electrons form covalent bond while the fourth covalent bond is formed due to germanium atom contribution and deficiency of one electron is left in form of hole.
4. The remaining fourth electron also tries to form a bond and treated as acceptor.
5. In *p*-type semiconductor, the majority carriers are holes while minority carriers are the electrons.

Que 3.13. Briefly describe :

i. Generation of carriers, and
ii. Recombination of carriers.

Answer

A. Generation of Carriers :

1. The process by which free electrons and holes are generated in pair is called generation of carriers.

2. When electrons in a valence band get enough energy, then they will absorb this energy and jumps into the conduction band. The electron which is jumped into a conduction band is called free electron and the place from where electron left is called hole.
3. Likewise, two types of charge carriers (free electrons and holes) get generated.

B. Recombination of Carriers :

1. The process by which free electrons and the holes get eliminated is called recombination of carriers.
2. When free electron in the conduction band falls in to a hole in the valence band, then the free electron and hole gets eliminate.

Que 3.14. Describe charge carrier concentration for *p*-type and *n*-type extrinsic semiconductor.

Answer

A. Charge Carrier Concentration for *p*-type Extrinsic Semiconductor :

1. We create a *p*-type extrinsic semiconductor by taking a group 4A element (like silicon) and doping small quantities of group 3A elements (like boron, aluminum, gallium, indium, thallium) into it.
2. These group 3A elements have one valence electron less, than that of silicon and so, they are potentially incapable of grabbing onto an electron or in other words releasing that vacant location. This releasing of vacant location is referred to as a hole.

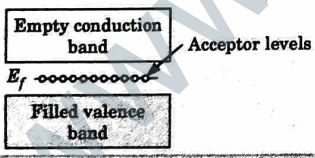


Fig. 3.14.1. *p*-type extrinsic semiconductor.

3. Now we have acceptor levels that can accept the electrons very easily, and acceptor levels are just above the valence band. Whereas, in a intrinsic semiconductor the Fermi energy level is right in the middle between the valence band and the conduction band. In the case of a *p*-type extrinsic semiconductor, it essentially lines up at the acceptor levels.
4. This changes the behaviour of the semiconductor quite dramatically. Now the charge carrier concentration is not solely dependent on temperature. For a significant fraction of temperature range, we find that the charge carrier concentration depends only on the dopant concentration.

5. So, if we increase the dopant concentration, then for that entire temperature range we will have a higher charge carrier concentration.
6. If we decrease the dopant concentration for the entire temperature range we will have lower charge carrier concentration. Again conductivity depends on the dopant concentration, because it depends on the charge carrier concentration.

B. Charge Carrier Concentration for *n*-type Extrinsic Semiconductor :

1. *n*-type extrinsic semiconductor has conceptually many similarities to the *p*-type except fundamentally the charge carrier is different here.
2. We create a *n*-type extrinsic semiconductor by taking a group 4A element (like silicon) and doping small quantities of group 5A elements (like nitrogen, phosphorus, arsenic, antimony, bismuth) into it.
3. These elements have essentially one additional valence electron available to them, and that valence electron is available for more free movement within the system and therefore, at very marginal availability of energy this electron begins to run around the system.
4. That is captured in the band diagram by this donor level (Fig. 3.14.2) which stays very close to the empty conduction band. So, at very small amount of energy we can get these donor electrons to get into the conduction band and then carry out the conduction processes.

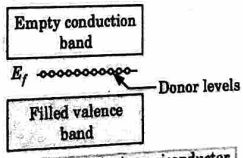


Fig. 3.14.2. *n*-type extrinsic semiconductor.

PART-4

Semiconductor Junctions : Metal-Semiconductor Junction and p-n Junction.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.15. Define metal-semiconductor junction. Discuss it in forward bias and reverse bias condition.

Answer

A. Metal-Semiconductor Junction :

1. Metal-semiconductor (M-S) junction is a type of electrical junction in which a metal comes in close contact with a semiconductor material.
2. Metal-semiconductor (M-S) junctions can behave as either Schottky barriers or as Ohmic contacts depending on the interface properties.
3. The principle of forming different types of the metal-semiconductor contact is the mismatch of the Fermi energy between metal and semiconductor material which is due to the difference in work functions.

B. M-S Junction in Forward Bias :

1. As a positive bias is applied to the metal, the Fermi energy of the metal is lowered with respect to the Fermi energy in the semiconductor. This results in a smaller potential drop across the semiconductor.
2. The balance between diffusion and drift is disturbed and more electrons will diffuse towards the metal than the number of electrons drifting into the semiconductor.
3. This leads to a positive current through the junction at a voltage comparable to the built-in potential.

C. M-S Junctions in Reverse Bias :

1. As a negative voltage is applied, the Fermi energy of the metal is raised with respect to the Fermi energy in the semiconductor.
2. The potential across the semiconductor now increases, yielding a larger depletion region and a larger electric field at the interface.
3. The barrier which restricts the electrons to the metal is unchanged so that barrier independent of the applied voltage limits the flow of electrons.

Que 3.16. Discuss *p-n* junction under no bias condition.

Answer

1. This is a two terminal device consisting of a *p-n* junction.
2. When *p*-type material is intimately joined (diffused) to *n*-type, a *p-n* junction is formed. Fig. 3.16.1 shows the *p-n* junction formation.

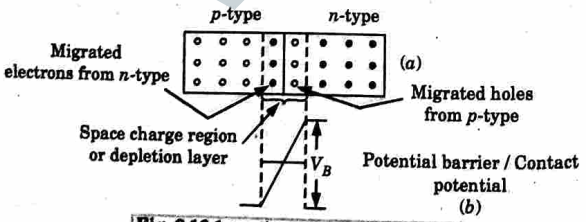


Fig. 3.16.1. *p-n* junction semiconductor.

3. As *p*-type has high concentration of holes and *n*-type has high concentration of free electrons, hence there is a tendency of holes to diffuse to *n*-side and electrons to *p*-side. The process is known as diffusion.
4. Thus, a region is formed which is known as depletion layer or charge free region or space charge region.
5. The diffusion of electrons and holes continues till a potential barrier is developed which prevents further diffusion and such condition is no bias condition for *p-n* junction.

Que 3.13. Discuss *p-n* junction in forward bias and reversed bias condition.

Answer

A. *p-n* Junction in Forward Bias :

1. For the forward bias of a *p-n* junction, *p*-type is connected to the positive terminal while the *n*-type to negative terminal of battery.

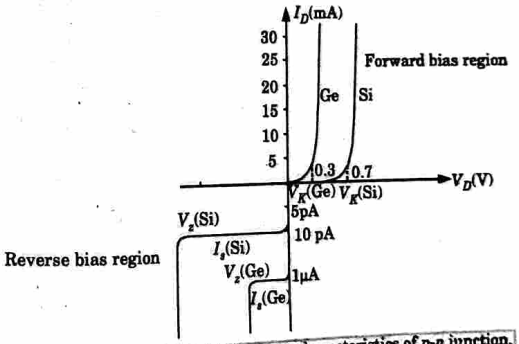


Fig. 3.17.1. Volt-ampere characteristics of *p-n* junction.

2. The potential can be varied with potential divider. At some forward voltage (0.3 V for Ge and 0.7 V for Si) the potential barrier is altogether eliminated and current starts flowing. This voltage is known as threshold or knee voltage (V_K).
3. As the forward applied voltage increases beyond threshold voltage, the forward current rises exponentially as shown in Fig. 3.17.1.
4. Beyond a certain safe value, it produces an extremely large current which may destroy the junction due to overheating.

B. *p-n* Junction in Reverse Bias :

1. The *p*-type is connected to the negative terminal while *n*-type is connected to the positive terminal of a battery.

2. In this case the junction resistance becomes very high and practically no current flows through the circuit.
3. In practical, a small current of the order of μA flows in the circuit due to minority carriers. This is known as reverse current. The reverse current is shown in Fig. 3.17.1.
4. As the reverse bias is increased from zero, the reverse current quickly rises to its maximum or saturation value. The slight increase is due to impurities on the surface which behaves as a resistor and hence obeys Ohm's law. This gives rise to a current called surface leakage current.
5. If the reverse voltage is further increased, the kinetic energy of electrons becomes so high that they knock out from the semiconductor atoms. At this stage breakdown of junction occurs and there is a sudden rise of reverse current. Now the junction is destroyed completely.
6. Thus, *p-n* junction is one way device which offers a low resistance when forward biased and behaves like an insulator when reverse biased.

PART-5

Essential Characteristics of Solar Photovoltaic Devices.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.18. Explain solar photovoltaic system. Also write its advantages and disadvantages.

Answer

A. Solar Photovoltaic System :

1. It refers to a wide variety of solar electricity systems.
2. This system use solar array made of silicon to convert sunlight into electricity.
3. Components other than PV array are collectively known as balance of system (BOS) which includes storage batteries, an electronic charge controller and an inverter.
4. Storage batteries with charge regulators are provided for back-up power supply during periods of cloudy day and during nights.
5. Batteries are charged during the day and supply power to loads.
6. The capacity of a battery is expressed in ampere-hours and each cell of the lead-acid battery is of 2 volts.

7. Batteries are installed with a microprocessor based charge regulator to monitor the voltage and temperature.
8. It also regulates the input and the output current to eliminate overcharging and excessive discharge respectively.
9. An inverter is provided for converting DC power from battery or PV array to AC power.
10. It needs to have an automatic switch-off in case the output voltage from the array is too low or too high.

B. Advantages of Solar Photovoltaic Systems :

1. No operational cost.
2. Low maintenance.
3. These systems are durable.
4. More flexibility is available in solar photovoltaic systems.
5. These systems are eco-friendly.

C. Disadvantages of Solar Photovoltaic Systems :

1. Low efficiency.
2. Weather dependent.
3. Installation cost is more.

Que 3.19. Write short note on :

i. Principle of solar photovoltaic, and
ii. Photovoltaic effect.

Answer

i. Principle of Solar Photovoltaic :

1. It is a field of solar energy utilization by which solar radiation is converted into electrical energy using a device called photovoltaic cell or solar cell.
2. A solar cell is made up of a semiconductor material like silicon (Si) or gallium arsenide (GaAs).
3. In semiconductors, atoms carry four electrons in the outer valence orbit, some of which can be dislodged to move freely in the materials, if extra energy is supplied.
4. Then, a semiconductor attains the property to conduct the current. This is the basic principle on which the solar cell works and generates power.

ii. Photovoltaic Effect :

1. Photoelectric effect is the emission of electrons or other free carriers when light hits a material.
2. When a solar cell is illuminated, electron-hole pairs are generated and the electric current I is obtained.
3. I is the difference between the solar light generated current I_L and the diode dark current I_f.

2. In this case the junction resistance becomes very high and practically no current flows through the circuit.
3. In practical, a small current of the order of μA flows in the circuit due to minority carriers. This is known as reverse current. The reverse current is shown in Fig. 3.17.1.
4. As the reverse bias is increased from zero, the reverse current quickly rises to its maximum or saturation value. The slight increase is due to impurities on the surface which behaves as a resistor and hence obeys Ohm's law. This gives rise to a current called surface leakage current.
5. If the reverse voltage is further increased, the kinetic energy of electrons becomes so high that they knock out from the semiconductor atoms. At this stage breakdown of junction occurs and there is a sudden rise of reverse current. Now the junction is destroyed completely.
6. Thus, *p-n* junction is one way device which offers a low resistance when forward biased and behaves like an insulator when reverse biased.

PART-5

Essential Characteristics of Solar Photovoltaic Devices.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.18. Explain solar photovoltaic system. Also write its advantages and disadvantages.

Answer

A. Solar Photovoltaic System :

1. It refers to a wide variety of solar electricity systems.
2. This system use solar array made of silicon to convert sunlight into electricity.
3. Components other than PV array are collectively known as balance of system (BOS) which includes storage batteries, an electronic charge controller and an inverter.
4. Storage batteries with charge regulators are provided for back-up power supply during periods of cloudy day and during nights.
5. Batteries are charged during the day and supply power to loads.
6. The capacity of a battery is expressed in ampere-hours and each cell of the lead-acid battery is of 2 volts.

7. Batteries are installed with a microprocessor based charge regulator to monitor the voltage and temperature.
8. It also regulates the input and the output current to eliminate overcharging and excessive discharge respectively.
9. An inverter is provided for converting DC power from battery or PV array to AC power.
10. It needs to have an automatic switch-off in case the output voltage from the array is too low or too high.

B. Advantages of Solar Photovoltaic Systems :

1. No operational cost.
2. Low maintenance.
3. These systems are durable.
4. More flexibility is available in solar photovoltaic systems.
5. These systems are eco-friendly.

C. Disadvantages of Solar Photovoltaic Systems :

1. Low efficiency.
2. Weather dependent.
3. Installation cost is more.

Que 3.19. Write short note on :

i. Principle of solar photovoltaic, and
ii. Photovoltaic effect.

Answer

i. Principle of Solar Photovoltaic :

1. It is a field of solar energy utilization by which solar radiation is converted into electrical energy using a device called photovoltaic cell or solar cell.
2. A solar cell is made up of a semiconductor material like silicon (Si) or gallium arsenide (GaAs).
3. In semiconductors, atoms carry four electrons in the outer valence orbit, some of which can be dislodged to move freely in the materials, if extra energy is supplied.
4. Then, a semiconductor attains the property to conduct the current. This is the basic principle on which the solar cell works and generates power.

ii. Photovoltaic Effect :

1. Photoelectric effect is the emission of electrons or other free carriers when light hits a material.
2. When a solar cell is illuminated, electron-hole pairs are generated and the electric current I is obtained.
3. I is the difference between the solar light generated current I_L and the diode dark current I_j.

4. Mathematically, $I = I_L - I_j$

$$= I_L - I_o\left[\exp\left(\frac{eV}{kT}\right) - 1\right]$$

Where, I_o = Saturation current,
e = Electronic charge,
T = Absolute temperature, and
k = Boltzmann's constant.
= 1.38×10^{-23} J/K.

Que 3.20. **Describe *V-I* and *P-V* characteristics of photovoltaic device.**

Answer

A. *V-I* Characteristic of Photovoltaic (PV) Device :

1. The *V-I* characteristic of a PV device is a non-linear graph between current and voltage generated by PV module as shown in Fig. 3.20.1.

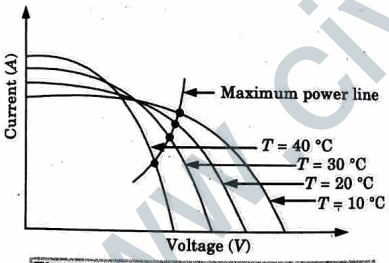


Fig. 3.20.1. *V-I* characteristics of a PV device.

2. For different temperature levels, different graphs have been plotted.
3. Maximum power points have also been shown to represent the point at which maximum power can be drawn from a PV device.
4. These maximum power point constitute the maximum power line (MPL).
5. MPL represents the track or path tracked by maximum power point tracker (MPPT).

B. *P-V* Characteristic of Photovoltaic Device :

1. *P-V* characteristic curve of a PV device is also a non-linear curve plotted between power and voltage of a PV device.
2. For different power densities in W/m², different graphs have been plotted between power and voltage of a PV module.

3. On the paper of these graphs, maximum power points are shown in Fig. 3.20.2.
4. The maximum power point (MPP) constitute, the maximum power line (MPL). MPL is also non-linear in nature.

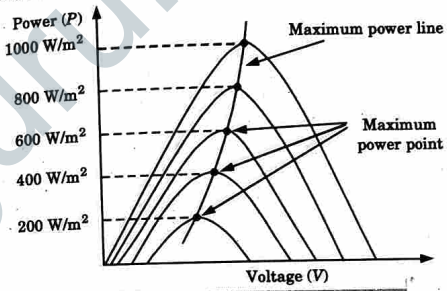


Fig. 3.20.2. *P-V* characteristic of a PV module.

PART-6

First Generation Solar Cells, Second Generation Solar cells, Third Generation Solar Cells.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.21. **What do you understand by first generation solar cells ? Explain their various types.**

Answer

A. First Generation Solar Cells :

1. These cell consists of a large area, single crystal, single layer *p-n* junction diode, capable of generating usable electrical energy from light sources with the wavelengths of sunlight.
2. These cells are typically made using a diffusion process with silicon wafers.
3. These silicon wafer based solar cells are the dominant technology in the commercial production of solar cells, accounting for more than 86 % of the terrestrial solar cell market.

B. Various types of First Generation Solar Cells :

a. Monocrystalline Silicon Cells :

1. In monocrystalline silicon cells, silicon is doped with boron to produce *p*-type semiconductor.
2. Monocrystalline rods are extracted from silicon and then sawed into thin plates or wafers.
3. The upper layer of the wafers is doped with phosphorous to produce *n*-type semiconductor. This becomes *p-n* junction.
4. Maximum efficiency of these cells is 24 %.

b. Polycrystalline Silicon Cells :

1. In polycrystalline cells, liquid silicon is poured into blocks that are sawed into plates.
2. During solidification of the material, crystal structures of varying sizes are formed.
3. The size of crystallites mainly depends upon the cooling condition. If the molten silicon is cooled very slowly, the crystallites of larger size are obtained.
4. The silicon solar cells made from polycrystalline silicon are low cost but low efficiency.
5. Maximum efficiency of these cells is 17.8 %.

c. Amorphous Silicon Cells :

1. If a silicon film is deposited on glass or another substrate material, this is so called amorphous or thin layer cell.
2. The layer thickness is less than 1 μm, so production costs are lower due to the low material costs.
3. However, the efficiency of amorphous cells is much lower than that of the other cells. Because of this, they are primarily used in low power equipment such as watches, pocket calculators etc.
4. Maximum efficiency of these cells is 13 %.

Que 3.22. Define second generation solar cells. Explain their types.

Answer

A. Second Generation Solar Cells :

1. These cells are based on the use of thin epitaxial deposits of semiconductors on lattice matched wafers.
2. There are two classes of epitaxial photovoltaic - space and terrestrial.
3. Space cells typically have higher efficiencies (28-30 %) in production, but also have a higher cost per watt.

4. There are currently a number of technologies / semiconductor materials under investigation or in mass production. Examples include amorphous silicon, polycrystalline silicon, micro-crystalline silicon, cadmium telluride, copper indium selenide / sulfide etc.
5. Second generation solar cells now comprise a small segment of the terrestrial photovoltaic market, and approximately 90 % of the space market.

B. Types of Second Generation Solar Cells :

a. Copper Indium (Gallium) Diselenide (CIS) Cell :

1. CIS has a direct band gap of 1.0 eV. Incorporation of Ga into the CIS mixture increases the band gap beyond 1.1 eV.
2. A heterogeneous junction with *n*-type Cd-S and *p*-type CIS is fabricated using thin-film technology.
3. Its main attraction is inexpensive preparation.
4. It is more stable as compared to a Si cell in outdoor applications and has efficiency of around 10 %. However, exposure to elevated temperatures results in loss of efficiency but light soaking restores it to original efficiency level.

b. Cadmium Telluride Cell :

1. Cd-Te has a favorable direct band gap of 1.44 eV.
2. Thin film heterogeneous junction with *n*-type Cd-S and *p*-type Cd-Te is fabricated as shown in Fig. 3.22.1.
3. Here, a transparent conducting oxide layer is used instead of metallic contact at the top on the *n* side.
4. EVA (ethylene vinyl acetate) is used for encapsulation.
5. Its efficiency is about 10 % and open circuit cell voltage is around 0.8 V.

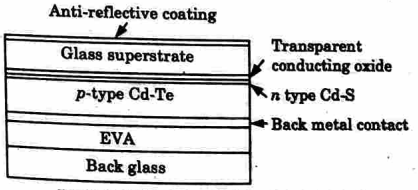


Fig. 3.22.1. Basic structure of Cd-Te cell.

Que 3.23. Define third generation solar cells. Explain their various types.

Answer

A. Third Generation Solar Cells :

1. They are proposed to be very different from the previous semiconductor devices as they do not rely on a traditional *p-n* junction to separate photogenerated charge carriers.
2. For space applications quantum well devices (quantum dots, quantum ropes, etc.) and devices incorporating carbon nanotubes are being studied with a potential for up to 45 % production efficiency.
3. For terrestrial applications, these new devices include photoelectrochemical cells, polymer solar cells, nanocrystal solar cells, dye sensitized solar cells and are still in the research phase.

B. Types of Third Generation Solar Cells :

a. Organic PV Cell :

1. The solar cells based on organic semiconductor can provide a low cost alternative for solar PV.
2. The thickness of the active layer of organic solar cells is only 100 nm thin, which is about 1000 times thinner than the crystalline silicon solar cells, and it is about 10 times thinner than the current inorganic thin film solar cells.
3. In the low material consumption per solar cell and the relatively simpler cell processing of organic semiconductors, there is a large potential for low cost large area solar cells.
4. Due to this reason, there is a considerable interest in organic photovoltaic devices.
5. Their principal advantage is that they are flexible and can bend without breaking, unlike Si, which is brittle.
6. They are also very light and cheap.
7. They may be folded or cut into required sizes and can still be used.

b. Dye Sensitized Solar Cell (DSC) :

1. The DSC can be considered as a thin film solar cell device. This technology is not yet commercialized but is on the verge of commercialization.
2. The DSC solar cells can be made flexible. It has a good potential for being a low cost solar cell technology.
3. This is mainly possible because of the large availability and low cost of the ingredient material as well as due to the low processing temperatures.
4. The DSC is a photo-electro-chemical device. In its operation it involves a photon, an electron and a chemical reaction.
5. The operation of DSC is considered similar to that of a photosynthesis process.

☺☺☺

UNIT 4

Conventional and Non-Conventional Energy Sources

CONTENTS

This is the subtitle of PDF, Use long text here.

PART-1

Biological Energy Sources and Fossil Fuels.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. Discuss various biological energy sources along with their merits and demerits.

Answer

Various biological energy sources are as follows :

a. Solar Energy :

1. Solar energy is a clean, cheap and abundantly available renewable energy and it is also the most important of the non-conventional sources of energy because it is non-polluting and therefore helps in decreasing the green house effect.
2. Solar energy can be used :
   - i. By direct conversion to a fuel by photosynthesis.
   - ii. By direct conversion to electricity by photovoltaic.
   - iii. By conversion to electricity via thermo-electric power system.
3. The sun releases the enormous amount of energy due to continuous fusion reaction taking place inside the sun.
4. The sun sends out the energy in the form of radiations at the rate of 3.7×10^{20} MW.
5. However, the energy intercepted by the earth is about 1.85×10^{11} MW.
6. This energy available is several times more than all the energy produced and consumed in the world.

i. Merits :

1. Noiseless operation.
2. Occupies less space on floor as there is no need of storage vessels.

ii. Demerits :

1. Solar equipments fail to work in nights, cloudy days or rainy season.
2. Large space is required for the collection of solar energy at a useful rate.

b. Hydro Energy :

1. It is a renewable energy source which is used to generate electricity.
2. Hydropower is obtained from water flow or falling water from a height.

3. Water stored behind dam and at a height has a lot of potential energy which is converted into mechanical and electrical energy.
4. The water is released gradually and is allowed to fall under the gravitational force and drive which rotate hydraulic turbines.
5. The generators attached with turbine produce the electricity.

i. Merits :

1. Hydropower does not pollute the water or the air during operation and no waste products are formed.

ii. Demerits :

1. It results in ecological disturbance like flooding situation and adverse effects on flora and fauna.

c. Wind Energy :

1. Wind energy is a renewable source of non-polluting energy and it has tremendous potential which if harnessed, can easily satisfy the energy demands of a country.
2. Estimates reveal that 2 % of the total solar energy falling on earth is converted to kinetic energy in the atmosphere.
3. 30 % of this kinetic energy occurs in the lowest 1000 m of elevation *i.e.*, wind in the lowest kilometer has maximum kinetic energy which can be converted into mechanical energy which in turn can be utilized to generate electricity or to perform some other useful work.
4. Since, the energy possessed by wind is by virtue of its motion, so the device used to extract its energy should be capable of slowing down the wind.

i. Merits :

1. Abundance availability for no price.
2. Useful at remote places for electricity generation.

ii. Demerits :

1. Less favourable in city locations as the wind is available at higher locations.
2. It is unreliable and intermittent. It is not available regularly.

d. Wave Energy :

1. The motion of the sea surface in the form of wind waves forms a source of energy.
2. Floating propellers are placed in shallow waters, near the shores and due to motion of the waves, the propellers also get the motion and this kinetic energy can be used to drive turbines.

i. Merits :

1. This is cheap, clean and inexhaustible source of energy.

2. Collector size of wave machines is comparatively smaller than solar devices.

ii. Demerits :

1. Corrosion of materials used in plant.

e. Geothermal Energy :

1. The energy harnessed from the hot rocks present inside the earth is called geothermal energy.
2. There is an increase in the temperature of the earth with increasing depth below the surface.
3. The fission of radioactive material naturally occurring in the rocks increases the temperature of the earth as we move down from the earth's surface.
4. Hot molten rocks called magma is present in the core of the earth. This causes sometimes volcanic action.
5. This hot steam is used to operate turbines to generate electricity.
6. Artificially it can also be harnessed with the help of pipes by drilling the hot rocks, which make the hot water to gush out through pipes which turns the turbine of the generator to produce electricity.

i. Merits :

1. It is cheap and clean source of energy.
2. Geothermal plants require little land area.

ii. Demerits :

1. Air pollution results in case of release of gases like H_2S, NH_3 present in the steam waste.
2. Noise pollution results from the drilling operations.

Que 4.2. Write short note on following :

i. Coal energy, and
ii. Natural gas

Answer

i. Coal Energy :

1. Coal is a conventional energy source.
2. It is formed due to degradation of trees and plants buried under layers of silt.
3. It is composed of mainly carbon and hydrocarbons.
4. Uses of coal :
   i. Coal is used to generate electricity. Power plants use coal for heating the water to generate steam which runs the turbines to generate electricity.

   ii. Coal is heated in furnace to make coke which is used to melt iron for making steel.
6. Environmental problems :
   i. Due to combustion of coal, carbon dioxide is produced which is responsible for causing global warming.
   ii. Coal also produces sulphur dioxide which is a cause for acid rain.

ii. Natural Gas :

1. Natural gas is formed by decomposition of dead animals and plants buried under the earth.
2. It is mainly composed of methane (CH_4) with small amount of propane and ethane.
3. Natural gas is the cleanest fossil fuel.
4. Uses of natural gas :
   i. It is used as a domestic and industrial fuel.
   ii. It is also used in thermal power plants for generating electricity.
5. Advantages of natural gas :
   i. Natural gas has a high calorific value and it burns without any smoke.
   ii. It can be easily transported through pipelines.

Que 4.3. What are conventional and non-conventional energy sources ? Write short notes on classification of energy sources.

AKTU 2019-20, Marks 10

Answer

A. Conventional (Non-Renewable) Energy Sources : These are the sources of energy which are exhaustible *i.e.*, cannot be replaced if once they are used.

Example : Coal, petroleum products, natural gas, etc.

B. Non-Conventional (Renewable) Energy Sources : These are the sources of energy which are inexhaustible *i.e.*, can be used to produce energy again and again.

Example : Sun, water, animal dung, agro-waste, wind, etc.

C. Classification of Energy Sources : Refer Q. 4.1, Page 4–2G, Unit-4.

PART-2

Fluid Dynamics, Power in the Wind, Available Resources, Fluids, Viscosity, Types of Fluid Flow, Lift.

7. This is the maximum energy available within that opening, hence

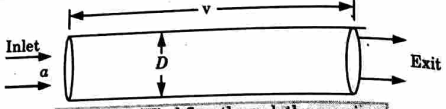


Fig. 4.6.1. Wind flow through the opening.

$$E_{max,\ wind} = \frac{\pi}{8}\rho D^2 v^3$$

Que 4.7. Write down the principle of power generation in wind mills. Derive an expression for maximum efficiency.

Answer

A. Principle of Power Generation in Wind Mills :

1. The basic principle of wind energy is to convert the kinetic energy of wind into rotational motion to operate an electric generator.

B. Expression for Maximum Efficiency :

1. The power in the wind can be extracted by allowing it to pass through moving wings that exert torque on a rotor.
2. The amount of power transferred is directly proportional to the density of the air, the area swept out by the rotor, and the cube of the wind speed.
3. Fig. 4.7.1 shows the air flow diagram on rotor, with variation of wind speed at different sections.

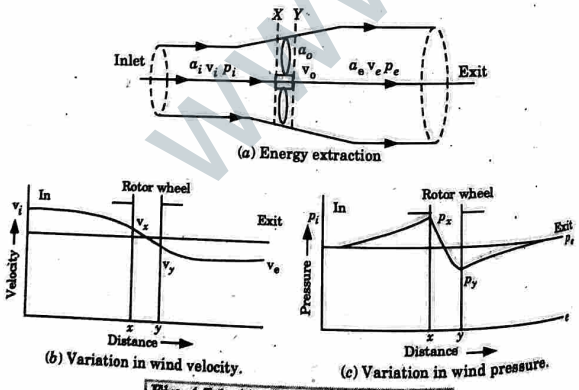


Fig. 4.7.1. Air flow through the rotor.

4. As the air passes through the rotor disk, there is a drop in static pressure such that pressure is below the atmospheric pressure while it leaves the blade.
5. The speed of the wind also gets reduced in the section (wake) and after this section the atmospheric pressure and speed of air again increases.
6. Let a_i and a_e = Inlet and outlet area of air enclosure,
   a_o = Rotor swept volume,
   v_i and v_e = Velocity of wind at inlet and outlet of enclosure,
   v_o = Velocity of rotor,
   ρ = 1.25, air density, and
   $\dot{m}$ = Mass flow rate of air over rotor.
7. The thrust on the turbine by moving air as it passes over the rotor,

$$F = \dot{m}(v_i - v_e) \qquad ...(4.7.1)$$

8. The power extracted by turbine,

$$P_T = \dot{m}(v_i - v_e)v_o \qquad ...(4.7.2)$$

9. Instantaneous loss in kinetic energy of wind as it passes through rotor,

$$P_W = \frac{1}{2}\dot{m}(v_i^2 - v_e^2) \qquad ...(4.7.3)$$

10. From eq. (4.7.2) and eq. (4.7.3), we have

$$\dot{m}(v_i - v_e)v_o = \frac{1}{2}\dot{m}(v_i^2 - v_e^2)$$

or
$$v_o = \frac{v_i + v_e}{2} \qquad ...(4.7.4)$$

11. From eq. (4.7.2) and eq. (4.7.4), we have

$$P_T = \dot{m}(v_i - v_e)\frac{(v_i + v_e)}{2} \qquad ...(4.7.5)$$

12. The mass flow rate through turbine rotor,

$$\dot{m} = \rho a_o v_o = \rho a_o \left(\frac{v_i + v_e}{2}\right) \qquad ...(4.7.6)$$

13. From eq. (4.7.5) and eq. (4.7.6), we have

$$P_T = \rho a_o \left(\frac{v_i + v_e}{2}\right)(v_i - v_e)\left(\frac{v_i + v_e}{2}\right)$$

$$P_T = \frac{1}{4}\rho a_o (v_i + v_e)(v_i^2 - v_e^2) \qquad ...(4.7.7)$$

14. For maximum power,

$$\frac{\partial P_T}{\partial v_e} = 0$$

$$3v_e^2 + 2v_i v_e - v_i^2 = 0$$

15. On solving, we get

$$v_e = \frac{1}{3} v_i$$

16. On putting this value in eq. (4.7.7), we get

$$P_{T,\max} = \frac{8}{27} \rho a_o v_i^3$$

17. The maximum efficiency of turbine is,

$$\eta_{max} = \frac{P_{T,\max}}{E_i} = \frac{8}{27} \times 2 \qquad \left(\because E_i = \frac{1}{2} \rho a_o v_i^3\right)$$

$$= 0.59$$

Que 4.8. Discuss some physical properties of fluids in brief.

Answer

Some physical properties of fluids are as follows :

a. **Density or Mass Density :** It may be defined as the mass per unit volume at a standard temperature and pressure. It is also known as specific mass. It is denoted by ρ and its unit is kg/m³.

Mathematically, $\rho = \frac{m}{v}$

Where, m = Mass (kg), and

v = Volume (m³).

b. **Weight Density :** It can be defined as the weight per unit volume at the standard temperature and pressure. It is also known as specific weight. It is denoted by W and its unit is N/m³.

Mathematically, $W = \frac{\text{Weight}}{\text{Volume}} = \frac{mg}{v} = \rho g \qquad \left(\because \frac{m}{v} = \rho\right)$

c. **Specific Volume :** It is defined as the volume per unit mass of fluid.

Mathematically, $V = \frac{v}{m} = \frac{1}{\rho}$

d. **Specific Gravity :** It is the ratio of the specific weight of the given fluid to the specific weight of a standard fluid.

$$S = \frac{\text{Specific weight of given fluid}}{\text{Specific weight of standard fluid}}$$

e. **Viscosity :** It is defined as the property of a fluid which determines its resistance to shearing stresses. Its SI unit is Pa-s and CGS unit is poise. An ideal fluid has no viscosity. It is a measure of the internal fluid friction which causes resistance to flow.

Que 4.9. Explain the following :

i. **Steady and unsteady flows,**
ii. **Laminar and turbulent flows,**
iii. **Rotational and irrotational flows,**
iv. **Compressible and incompressible flows, and**
v. **Uniform and non-uniform flows.**

Answer

i. **Steady and Unsteady Flows :**

1. Steady flow is that type of flow in which the fluid characteristics like velocity, pressure, density, etc., at a point do not change with time.
2. Unsteady flow is that type of flow in which the velocity, pressure, density, etc, at a point changes with respect to time.

ii. **Laminar and Turbulent Flows :**

1. Laminar flow is one in which the fluid particles move along well defined paths or stream line and all the stream lines are straight and parallel.
2. Turbulent flow is that type of flow in which the particles move in a zig-zag way.

iii. **Rotational and Irrotational Flows :**

1. Rotational flow is that type of flow in which the fluid particles while flowing along stream lines also rotate about their own axis.
2. If the fluid particles while flowing along stream lines, do not rotate about their own axis that type of flow is called irrotational flow.

iv. **Compressible and Incompressible Flows :**

1. Compressible flow is that type of flow in which the density of the fluid changes from point to point.
2. Incompressible flow is that type of flow in which the density is constant for the fluid flow.

v. **Uniform and Non-uniform Flows :**

1. Uniform flow is defined as that type of flow in which the velocity at any given time does not change with respect to space.
2. Non-uniform flow is that type of flow in which the velocity at any given time changes with respect to space.

Que 4.10. Write short note on following :

i. **Subsonic, sonic and supersonic flows,**
ii. **Subcritical, critical and supercritical flows, and**
iii. **One, two and three dimensional flows.**

Answer

i. Subsonic, Sonic and Supersonic Flows :

1. When Mach number is less than 1 ($M < 1$), flow is subsonic flow.
2. When Mach number is equal to 1 ($M = 1$), flow is sonic flow.
3. When Mach number is greater than 1 ($M > 1$), flow is supersonic flow.

ii. Subcritical, Critical and Supercritical Flows :

1. When Froude number is less than one ($Fe < 1$), the flow is subcritical flow.
2. When Froude number is equal to one ($Fe = 1$), the flow is critical flow.
3. When Froude number is greater than one ($Fe > 1$), the flow is supercritical flow.

iii. One, Two and Three Dimensional Flows :

1. One dimensional flow is that type of flow in which the flow parameter such as velocity is a function of time and one space co-ordinate only.
2. Two dimensional flow is that type of flow in which the velocity is a function of time and two rectangular space co-ordinates.
3. Three dimensional flow is that type of flow in which the velocity is a function of time and three mutually perpendicular directions.

Que 4.11. Explain the force exerted by a flowing fluid on a stationary body.

Answer

1. The total force (F_R) exerted by the fluid on the body is perpendicular to the surface of the body. Thus the total force is inclined to the direction of motion.
2. The component of total force (F_R) in the direction of flow is called drag and is given as,

$$F_D = C_D \frac{a\rho v^2}{2}$$

Where, C_D = Coefficient of drag.

3. The component of total force (F_R) in the direction perpendicular to the direction of flow is known as lift and is given as,

$$F_L = C_L \frac{a\rho v^2}{2}$$

Where, C_L = Coefficient of lift.

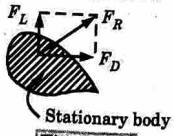


Fig. 4.11.1.

PART-3

Wind Turbine Dynamics and Design.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.12. Discuss the following parameters :

i. **Pitch angle**
ii. **Pitch control**
iii. **Tip speed ratio**
iv. **Solidity**
v. **Angle of inclination**
vi. **Angle of incidence**
vii. **Nacelle**
viii. **Yaw control.**

Answer

i. **Pitch Angle (β) :** Angle between the direction of wind and direction perpendicular to the plane of blades is known as pitch angle.

ii. **Pitch Control :** It is the control of pitch by turning the blades or blade tips.

iii. **Tip Speed Ratio :** The ratio of the speed of the rotor blade tips to the speed of the wind is known as tip speed ratio.

iv. **Solidity :** It is defined as the percentage of the circumference of the rotor which is filled by the rotor blades.

$$\text{Solidity } (s) = \frac{Nb}{\pi d}$$

Where, N = Number of blades,
b = Average breadth of blade, and
d = Diameter of the circle described by a blade.

v. **Angle of Inclination (I) :** It is the angle between the relative velocity vector and the plane of rotation.

vi. **Angle of Incidence (i) :** It is the angle between the relative velocity vector and the chord line of aero file.

vii. **Nacelle :** It is the assembly consists of wind turbine, gears, bearings, generator etc., mounted in a housing.

viii. **Yaw Control :** Control of orienting the axis of wind turbine in the direction of wind is known as yaw control.

Que 4.13. Discuss the aerodynamic consideration in wind mill design.

Answer

1. Aerodynamics is the branch of science which deals with air and gases in motion and their mechanical effects.
2. Nomenclature of aerodynamics is as given below :

   v = Impinging wind velocity,
   v_T = Wind velocity in plane of rotation due to blade turning,
   v_R = Resultant wind velocity,
   F_L = Lift force perpendicular to v_R,
   F_D = Drag force perpendicular to v_R,
   F_R = Resultant force on blade,
   F_T = Component of F_R producing torque,
   F_{th} = Thrust force component,
   α = Angle of attack, and
   β = Pitch angle.

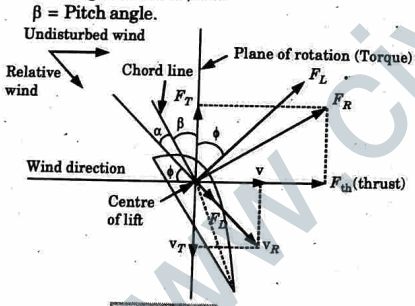


Fig. 4.13.1.

3. Blade is moving in the plane of rotation and it sees a tangential wind velocity v_T in the plane of rotation.
4. v_R is the resulting wind velocity, which is the vector sum of tangential velocity v_T and impinging wind velocity v.
5. The lift force F_L acts perpendicular to the resultant velocity v_R and the drag force F_D is parallel to v_R.
6. The vector sum of lift force F_L and drag force F_D is F_R.
7. Now resolve F_R into two forces *i.e.*, F_T which is torque producing component and F_{th} thrust producing component.
8. The tower and structural members of the wind turbine must be designed to withstand F_{th}.
9. The vector diagram is centred on the centre of lift of the aerodynamic blade.

10. The angle of attack (α) is very important parameter and it determines lift and drag forces.

Que 4.14. Describe various parameters of designing of wind turbine rotor.

Answer

Various parameter of designing of wind turbine rotor are as follows :

a. Diameter of the Rotor :

1. The diameter of the rotor is determined from the operating wind speed and the rated power output.
2. The generated power is given by,

$$P = P_0 \eta_e \eta_m C_p$$
$$= \frac{1}{2} \rho A v_\infty^3 \eta_e \eta_m C_p$$
$$= \frac{1}{8} \pi \rho D^2 v_\infty^3 \eta_e \eta_m C_p$$

Where, η_m = Efficiency of mechanical transmission and
η_e = Efficiency of electrical generation.

b. Choice of the Number of Blades :

1. It is obvious that the efficiency of power extraction from wind depend on the proper choice of the number of blades.
2. There will be little power extraction if the blades are so close to each other or rotate so fast that every blade moves into the turbulent air created by the preceding blade.
3. It will also be less than optimum if the blades are so far apart or move so slowly that much of the air stream passes through the wind turbine without interacting with a blade.
4. Thus, the choice of the number of blades should depend on the TSR (tip speed ratio).

c. Choice of the Blade Profile and Material :

1. For low TSR water pumping wind mills, the blade is generally a flat metallic plate.
2. In some cases it is a simple, circularly curved metallic sheet, which leads to certain aerofoil-like characteristics, but with uniform thickness throughout the blade. Because of their low rigidity, these blades have to be fixed to a circular metallic frame for structural support.

d. Choice of the Pitch Angle :

1. The pitch angle is given by $\beta = I - i$.
2. As I vary along the length of the blade, β should also vary to ensure an optimal angle of incidence at all points of the blade. Thus the desirable twist along the blade can be calculated easily.

e. The Tower :

1. In a horizontal axis wind turbine, the tower supports the whole machinery, including the blades, the gear box, the generator, and the control equipment.
2. It therefore requires high strength which is achieved with a steel or concrete structure based on tubular or lattice construction.
3. It is necessary to avoid amplification of vibration through careful design of the resonant frequencies of the tower, blades, rotor, etc.

f. Transmission System and Gear Box :

1. In general, the optimal speed of rotation of an electrical generator is much higher than the optimal speed of a wind turbine.
2. In order to ensure that a low speed of the turbine produces a high rotational speed at the generator, a gear box is inserted in the transmission system.
3. If the great system has fixed gear ratio, the transmission system is relatively simple and inexpensive.

PART-4

Wind Farms.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.15. Write a short note on wind farms.

Answer

1. Wind farms or wind parks often have many turbines generator units.
2. The wind farms are open spaces away from forest, cities and mountains so that average annual wind speed should not be less than 7 m/s and not away from the distribution centre.
3. Since each turbine extracts some of the energy of the wind, it is important to provide adequate spacing between turbines to avoid excess energy loss.
4. A wind farm has 10-50 turbines unit depending on its size.
5. Where land area is sufficient, turbines are spaced three to five rotor diameters apart perpendicular to the prevailing wind, and five to ten rotor diameters apart in the direction of the prevailing wind, to minimize the loss inefficiency.

Que 4.16. What parameters are to be considered while selecting a site for wind farms ?

Answer

Parameters to be considered while selecting a site for wind farms are as follows :

1. Flat open area should be selected, as the wind velocities are high in flat open area.
2. The proposed altitude is to be selected by taking average wind speed data.
3. Minimum wind speed should be available throughout the year.
4. Ground surface should be stable and high soil strength.
5. To minimize the transmission losses, the wind power should be near the consumers.
6. It should be at least 5 km away from the cities to reduce the effect of noise pollution.
7. Low land cost.
8. Approach roads upto site.

PART-5

Geothermal Power and Ocean Thermal Energy Conversion.

CONCEPT OUTLINE

Geothermal Energy : The enormous amount of energy available inside the earth in the form of heat is known as geothermal energy. Geothermal energy is a form of renewable energy and independent of sun, having the source of natural heat inside the earth.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.17. Discuss different systems used for generating the power using geothermal energy.

Answer

Different systems used for generating the power using geothermal energy are given below :

This is the subtitle of PDF, Use long text here.

a. Vapour Dominated Power Plant :

1. In a vapour dominated power plant, steam is extracted from geothermal wells, passed through a separator to remove particulate contents and flows directly to a steam turbine.
2. Steam then operates the turbine coupled with the generator at a temperature of about 245 °C and pressure 7 bar which are less than those in conventional steam cycle plants.
3. Thus, the efficiency of geothermal plants is low, *i.e.*, about 20 %.
4. Exhaust steam from the turbine passes through a condenser and the water so formed circulates through the cooling tower.
5. It improves the efficiency of the turbine and controls environmental pollution associated with the direct release of steam into the atmosphere.
6. Waste water from the cooling tower sump is re-injected into the geothermal well to ensure continuous supply.

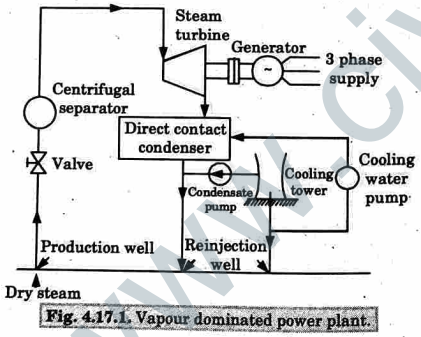


Fig. 4.17.1. Vapour dominated power plant.

b. Liquid Dominated Power Plants :

1. These plants are also called wet steam plants because they give wet steam *i.e.*, a mixture of hot water and steam under high pressure.
2. There are two types of liquid dominated power plants :

i. Flashed Steam System :

1. Flashed system is preferred for high temperature mixture of geothermal brine and steam with low dissolved impurities.

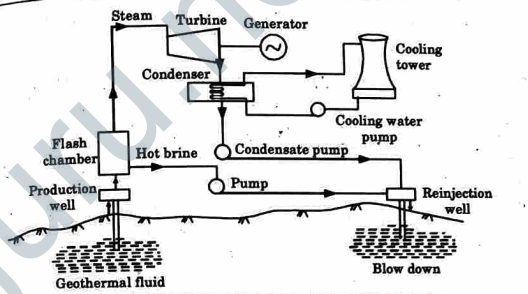


Fig. 4.17.2. Flashed steam geothermal power plant.

2. Geothermal fluid (mixture of brine and steam) passes through a flash chamber where a large part of the fluid is converted to steam.
3. Dry saturated steam passes through the turbine coupled with the generator to produce electric power.
4. Hot brine from the flash chamber and the turbine discharges from the condenser are re-injected into the ground and reinjection of the spent brine ensures a continuous supply of geothermal fluid from the well.

ii. Binary Cycle System :

1. A binary cycle is used where geothermal fluid is hot water with temperature less than 100 °C.

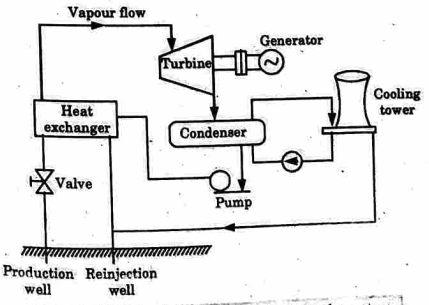


Fig. 4.17.3. Schematic view of binary cycle system.

This is the subtitle of PDF, Use long text here.

2. This plant operates with a low boiling point working fluid in a thermodynamic closed Rankine cycle.
3. Hot brine from underground reservoir circulates through a heat exchanger and is pumped back to the ground.
4. In heat exchanger, hot brine transfers its heat to the organic fluid thus converting it to a superheated vapour that is used in a standard closed Rankine cycle.

Que 4.18. Write the difference between geothermal power plant and thermal power plant. **AKTU 2019-20, Marks 10**

Answer

S. No.	Geothermal Power Plant	Thermal Power Plant
1.	It uses inexhaustible source of energy.	It uses exhaustible source of energy.
2.	It is more environment friendly	It is less environment friendly.
3.	These power plants in some dangerous cases can cause earthquakes.	There is no such problem.
4.	It is mainly used for power generations process.	It can be used for various industrial processes.
5.	Set up cost is high.	Set up cost is low.
6.	By-products of these plants are not used.	By-products of these plants can be used.
7.	These plants are less flexible.	These plants are more flexible.
8.	Specified areas are required.	No such restriction.

Que 4.19. What is the working principle of ocean thermal energy conversion ?

Answer

1. The principle of ocean thermal energy conversion (OTEC) is that there is a temperature difference between water at the bottom of the sea and the water at the top.
2. This temperature difference can be used to operate a heat engine and most of the radiation is being absorbed at the surface layer of water.

3. The mixing between hot and cold water is prevented because no thermal convection occurs between hot and cold water layer. This means that the surface layer will act as a source and cold layers act as a sink.
4. Therefore, it is essential to connect the reversible heat engine between source and cold sink to produce work that can be converted into required applications.

Que 4.20. What are the types of OTEC system ?

Answer

Following are the two basic types of OTEC system :

a. Closed or Anderson Cycle OTEC System :

1. In this system, the working fluids for heat engines use the fluids like ammonia, freon 12, butane gas having low boiling point because the working temperature of sea water is small.
2. Warm water from ocean surface is circulated through a pump to a heat exchanger which acts as boiler to generate freon vapour at high pressure.
3. This vapour expands in the turbine to develop mechanical power and it is used to drive an electric generator which produces electric energy.
4. Freon vapour from turbine at low pressure is condensed in the condenser with the help of cold water drawn from the depth of ocean through a pump. The overall efficiency of such plant is very low in the range of 2 to 3 % only.

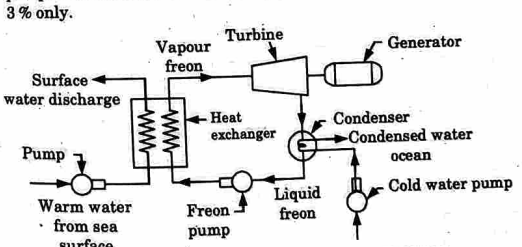


Fig. 4.20.1. Closed or Anderson cycle OTEC plant.

b. Open Cycle or Claude Cycle OTEC System :

1. In this system, the warm water from ocean surface is admitted through the deaerator to the flash evaporator which is maintained under high vacuum.
2. As a result, a low pressure steam is generated due to throttling effect and the remainder liquid is discharged back to the ocean at high depth.
3. The deaerator also removes the dissolved non-condensable gases from water before supplying to the evaporator.

This is the subtitle of PDF, Use long text here.

4. This low pressure steam having very high specific volume is supplied to turbine where it expands and the mechanical power so developed is converted into electrical power by the generator.
5. The exhaust steam from turbine is discharged into a direct contact type heat exchanger and mixes with the cold water drawn from ocean at a depth of about 1 to 2 km.
6. The mixture of condensed steam and ocean cold water are discharged into the ocean.

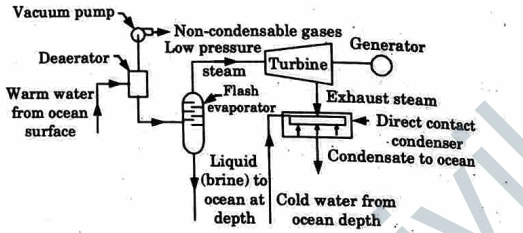


Fig. 4.20.2. Open or Claude cycle OTEC system.

PART-6

Tidal Power

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.21. What are tides ? How they are formed ?

Answer

1. Tides are generated by the action of gravitational forces of the sun and the moon in the ocean, by the spinning of the earth about its axis and the relative positions of the earth, moon and the sun.
2. The highest level of tidal water is known as high tide and the lowest level of tidal water is known as low tide.
3. The level of difference between high and low tides is called tidal range.
4. The tides are the periodic vertical rise and fall of ocean water.
5. The tidal rise and fall of water accompanied by periodic horizontal to and fro motion of water is called tidal currents.

6. The tidal currents flow in horizontal direction and have kinetic energy. This energy is called tidal current energy.
7. The rise and fall of the water level follows a sinusoidal curve.
8. Point *A* indicates the high tide point and *B* indicates low tide point.
9. The tidal range (*R*) is the difference between consecutive high tide and low tide water levels.

R = (High tide level) – (Low tide level)

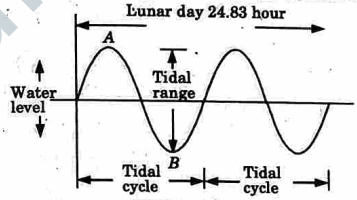


Fig. 4.21.1.

Que 4.22. Explain with sketches the various methods of tidal power generation. Write the advantages and limitations of tidal power.

OR

How tidal power plants are classified and what are the limitations of tidal power plant ? **AKTU 2019-20, Marks 10**

Answer

A. **Principle :** To utilize tidal energy, water must be trapped at high tide behind a dam or barrage and then made to drive turbine as it returns to sea during low tides. The available energy is proportional to the square of the amplitude.

B. **Components of Tidal Power Plant :** Main components of a tidal power plant are :

a. **Barrage :** It is a dam of low head and requires the following features :
1. Less sloppy towards the ocean and basin side.
2. It should be able to withstand the shock load of tides and wave.
3. Low height and shorter in length to minimize the cost of construction.
4. Steel foundation frame and channels are embedded in the ducts within the barrage for turbine and gates steel foundation.

b. **Sluice Gates :** These gates are opened by water pressure and no mechanical means is required.

c. **Turbine :** The Kaplan or bulb type turbine is used to operate with low head and the entire turbine generator unit is submerged in the water.

is created by pressure differences in the earth atmosphere due to unequal solar heating.

2. The energy transferred to water by wind is kinetic as well as potential energy and it depends upon the wind speed, blowing time of wind, and distance of wind travel over the sea.
3. The blowing wind creates a pressure over the surface of ocean water and air pushes down each particle, which again comes up. So, it actually moves up and down in circular path.
4. Every particle passes on its motion to the next. This movement of the water particles produces a pattern, which we see as wave.
5. These waves travel a long distance as they propagate and are continuously strengthened by the new wind as they pass and retain their energy even winds die down.
6. The ocean wave energy is created because of periodic to and fro, up and down motion of water particles in the form of progressive waves.
7. It is important to note that water does not travel with wave while the disturbance or wave travels in wind direction.
8. The height of the wave depends on the speed of the wind.
9. These waves develop for few seconds and get superimposed on ocean water.
10. The power potential of these waves can be converted to electricity by mechanical means and harnessing this oceanic energy of waves has been developed over past 30 years using wave machines.

Que 4.24. What are the advantages and disadvantages of wave power ?

Answer

A. Advantages of Wave Power :

1. It is a concentrated form of energy and can naturally accumulate over time.
2. It is an ecofriendly renewable source of energy.
3. No space coverage on land as required by wind and solar devices.
4. Large concentrated power carried in wave's motion.
5. The running cost is negligible as this energy is available free of cost.

B. Disadvantages of Wave Power :

1. The device operates in ocean and needs consideration for construction, maintenance, and reliability.
2. Capital cost of system is high.
3. Problem in maintenance occurs.

PART-8

Hydropower.

CONCEPT OUTLINE

Hydropower : It is the power derived from the energy of falling or fast running water which may be harnessed for useful purpose.

Application of Hydropower :

1. Controlling the floods in the rivers.
2. Storage of irrigation water.
3. Storage of the drinking water supply besides generation of power.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.25. What do you mean by hydroelectric power plant ?

Answer

1. Hydroelectric power plant converts the hydraulic energy of water into electrical energy.
2. The level of any place is higher than sea level, thus rain water falling over the earth's surface possesses potential energy relative to sea or ocean and flows towards sea.
3. This datum (potential) energy (head) of rain water available at appreciable vertical height is converted into mechanical energy by allowing the water to flow through the hydraulic turbine runner.
4. The mechanical energy is then utilized to run an electric generator coupled to the turbine shaft.
5. Hydroelectric projects have long useful life extending over 50 years and help in opening of avenues for the development or remote and backward areas.
6. Nearly 20 percent of the total power requirement of the world is met by hydroelectric power plants.

Que 4.26. Give general layout and function of essential element of hydroelectric power plant.

This is the subtitle of PDF, Use long text here.

Answer

A. **General Layout :** Fig. 4.26.1 shows a general layout of a hydroelectric power plant in which an artificial storage reservoir formed by constructing dam has been shown.

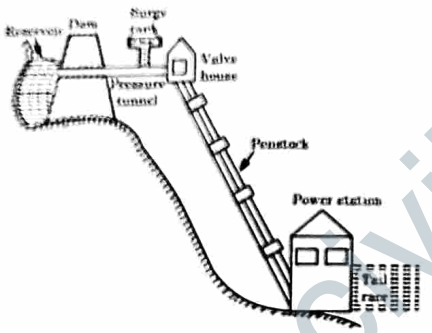


Fig. 4.26.1. General layout of a hydroelectric power plant.

B. **Functions of Essential Element of Hydroelectric Power Plant :**

i. **Reservoir :** Its purpose is to store water which may be utilised to run the prime mover to produce electrical power.

ii. **Dam :** The function of dam is to provide a head of water to be utilised in the water turbine.

iii. **Trash Rack :** The purpose of providing a trash rack is to prevent entry debris which might damage the wicket gates and turbines runners or mean choking of nozzles of the impulse turbines.

iv. **Forebay :** The forebay serves as a regulating reservoir storing water temporarily when load on the plant is reduced and providing water for initial increase on account of increasing load during which time water in the canal is being accelerated.

v. **Surge Tank :** This may be considered as an additional storage space near the turbine, usually provided in high head, medium head plants when there is a considerable distance between the water source and turbine which necessitates a long penstock.

vi. **Penstock :** It is a conduit system for taking water from the intake works and forebay to the turbines.

vii. **Spillway :** This may be considered a sort of safety valve for a dam. A spillway serves to discharge excess in the reservoir beyond the full permissible level.

viii. **Power House :** It is generally located at the foot of the dam and near the storage reservoir.

ix. **Prime mover :** The purpose of prime mover is to convert kinetic energy of water into mechanical energy.

This is the subtitle of PDF, Use long text here.

UNIT 5

Systems and Synthesis

CONTENTS

PART-1

Overview of World Energy Scenario.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. Discuss in brief about the different world energy scenarios.

Answer

Majorly there are three world scenarios which are discussed as :

a. Modern Jazz :

1. It is a market led, digitally disrupted world with faster paced and more uneven economic growth.
2. Recent signals suggest that this entrepreneurial future might accelerate clean energy access on both global and local scales, presenting new systems integration, cyber security and data privacy challenges.

b. Unfinished Symphony :

1. It is a strong, coordinated, policy led world, with long term planning and united global action to address connected challenges, including inequitable access and affordable decarbonization.
2. Recent signals suggest increased activism and commitment to addressing climate change at the sub-national level and an expansion of the focus from climate change mitigation to a broader, socially inclusive and economically affordable, sustainable development agenda.

c. Hard Rock :

1. It is a fragmented world with inward looking policies, lower growth and less global cooperation.
2. Recent signals, such as the rise of populist leaders and uncertainty about the outlook for international cooperation, imply that this scenario is also evolving into a story of regionally firmer security foundations rather than total fragmentation and harder rocks.

Que 5.2. Discuss data of energy consumption in India.

OR

Review the energy scenario in India in brief.

AKTU 2019-20, Marks 10

This is the subtitle of PDF, Use long text here.

Answer

1. In India, in 1947, the total power generation capacity was only 1360 MW, and by 1991 it grew to 65,000 MW, of which 69 % (45,000 MW) was generated in thermal plants.
2. The distribution of energy in various plants is as follows :

i. Hydro Plant :

1. The total Indian hydro-potential is 84,000 MW.
2. The installed capacity is 18,443 MW (March, 1991) compare to 200 kW in 1897 (Darjeeling) and 508 MW at the time of independence.

ii. Nuclear Power Plant : Presently, in India, about 2.3 % of generating capacity is nuclear based. This corresponds to about 1,500 MW of the installed capacity comprising 8 units.

iii. Coal Plant :

1. Coal power plants are now getting maximum attention, since coal is abundantly available and the implementation time is relatively short.
2. Thermal power generation capacity during the 8th Plan is 28,000 MW and during 9th Plan is 32,000 MW.

iv. Renewable Energy :

1. Renewable energy hardly makes any contribution to the total energy production.
2. However, construction of a 100 MW ocean thermal energy conversion (OTEC) project has commenced.

PART-2

Nuclear Radiation, Fuel Cycle.

CONCEPT OUTLINE

Nuclear Fuel Cycle : It is the progression of nuclear fuel through a series of differing stages. It consists of steps in the front end, which are the preparation of fuel, steps in the service period in which fuel is used during reactor operation and steps in the back end which are necessary to safely manage the operation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.3. Define nuclear radiation with example. Also give types of nuclear radiation.

Answer

A. Nuclear Radiation :

1. Nuclear radiation refers to the particles and photons emitted during reactions that involve the nucleus of an atom. It is also known as ionizing radiation.
2. The particles emitted by nuclear reactions are sufficiently energetic that they can remove electrons from atoms and molecules and ionize them.
3. Nuclear radiation includes gamma rays, *X*-rays, and the more energetic portion of the electromagnetic spectrum.
4. Ionizing subatomic particles released by nuclear reactions include alpha particles, beta particles, neutrons, positrons, and cosmic rays.

Example : Fission of U-235.

B. Types of Nuclear Radiation :

i. Alpha Radiation :

1. Alpha radiation occurs when an atom undergoes radioactive decay, giving off a particle called an alpha particle consisting of two protons and two neutron.
2. Due to their charge and mass, alpha particles interact strongly with matter, and only travel a few centimeters in air.
3. Alpha particles are unable to penetrate the outer layer of dead skin cells, but are capable, if an alpha emitting substance is ingested in food or air, of causing serious cell damage.

ii. Beta Radiation :

1. Beta radiation takes the form of either an electron or a positron being emitted from an atom.
2. Due to the smaller mass, it is able to travel further in air, up to a few meters, and can be stopped by a thick piece of plastic, or even a stack of papers. It can penetrate skin a few centimeters, posing somewhat of an external health risk.

iii. Gamma Radiation :

1. Gamma radiation, unlike alpha or beta, does not consist of any particles, instead consisting of a photon of energy being emitted from an unstable nucleus.
2. Having no mass or charge, gamma radiation can travel much farther through air than alpha or beta, losing (on average) half its energy for every 500 feet.

iv. *X*-Rays :

1. *X*-rays are similar to gamma radiation with the primary difference being that they originate from the electron cloud.

This is the subtitle of PDF, Use long text here.

2. This is generally caused by energy changes in an electron, such as moving from a higher energy level to a lower one, causing the excess energy to be released.

PART-3

Waste and Proliferation, Climate Change.

CONCEPT OUTLINE

Nuclear Waste : Radioactive by products resulting from fusion, fission, refinement or processing of radioactive materials is known as nuclear waste.

Climate Change : It refers to the significant changes in global temperature, precipitation and wind patterns, etc., that occur over several decades or longer.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.4. **What are the sources and types of nuclear waste ?**

Answer

A. Sources of Nuclear Waste :

i. Nuclear Fuel Cycle :

1. Waste from the front end of the nuclear fuel cycle is usually alpha-emitting waste from the extraction of uranium. It often contains radium and its decay products.
2. The back end of the nuclear fuel cycle contains fission products that emit beta and gamma radiation, and actinides that emit alpha particles, such as U-234.

ii. Nuclear Weapon Decommissioning :

1. Waste from nuclear weapons decommissioning is unlikely to contain much beta or gamma activity other than tritium and americium.
2. It is more likely to contain alpha-emitting actinides such as Pu-239 which is a fissile material used in bomb.

iii. Legacy Waste :

1. This waste is due to historic activities typically related to radium industry, uranium mining, and military programs, numerous sites contain or are contaminated with radioactivity..

iv. Medicine :

1. Radioactive medical waste tends to contain beta particle and gamma ray emitters.

v. Industry :

1. Industrial source waste can contain alpha, beta, neutron or gamma emitters. Gamma emitters are used in radiography while neutron emitting sources are used in a range of applications, such as oil well logging.

B. Types of Nuclear Waste :

i. Low Level Waste :

1. Mainly generated from nuclear fuel cycle, low level nuclear waste includes materials that have been contaminated by radioactive substances.
2. The waste also includes items that gain radioactive property after getting exposed to neutron radiation.
3. The low level nuclear waste consists of clothing, wiping rags, mops, filters, reactor water treatment residues, equipments and tools, luminous dials, medical tubes, swabs, and injection needles, among others.

ii. Intermediate Level Waste :

1. As it contains higher amounts of radioactive materials compared to low level waste, the waste requires special shielding.
2. The waste comprises chemical sludge, resins, nuclear reactor parts and contaminated materials from decommissioned reactors.

iii. High Level Waste :

1. It is a waste produced after nuclear fuel is burnt and removed from the nuclear reactors.
2. The waste comprises highly radioactive fission products and transuranic elements produced in the core of a nuclear reactor.

Que 5.5. **Write a short note on proliferation concerns related to the nuclear waste.**

Answer

1. Since uranium and plutonium are nuclear weapons materials, there have been proliferation concerns.
2. Ordinarily, plutonium is reactor-grade plutonium. In addition to Pu-239, which is highly suitable for building nuclear weapons, it contains large amounts of undesirable contaminants such as Pu-240, Pu-241, and Pu-238. These isotopes are extremely difficult to separate, and more cost effective ways of obtaining fissile material exist .

3. High level waste is full of highly radioactive fission products, most of which are relatively short-lived.
4. This is a concern since if the waste is stored, perhaps in deep geological storage, over many years the fission products decay, decreasing the radioactivity of the waste and making the plutonium easier to access.
5. The undesirable contaminant Pu-240 decays faster than the Pu-239, and thus the quality of the bomb material increases with time although its quantity decreases during that time as well.
6. These all concerns lead to think over the invention of such a technology that can help in reducing the proliferation of nuclear waste.

Que 5.6. What are the causes and effects of climate change ?

Answer

A. Causes of Climate Change :

i. Greenhouse Gases :

1. Greenhouse gases play a vital role in the earth's climate cycles. As the planet gets hit with the sun's rays, some of the energy is absorbed, and the rest of that energy and heat get reflected into space.
2. Greenhouse gases in the atmosphere trap the reflected energy, redirecting it back down to the earth and eventually contributing to global warming.
3. While some of these greenhouse gases, such as water vapour, are naturally occurring, others, such as CFCs, are synthetic. CO_2 is released into the atmosphere from both natural and human made causes and is one of the leading contributors to climate change.

ii. Deforestation :

1. Deforestation and climate change often go hand in hand. Not only does climate change increase deforestation by way of wildfires and other extreme weather, but deforestation is also a major contributor to global warming.
2. Deforestation is the second leading contributor to global greenhouse gases or climate change.

iii. Human Activities :

1. The most significant contributor to climate change is the burning of fossil fuels for electricity, heat, and transportation.
2. Of these factors, transportation in the form of cars, trucks, ships, trains, and planes emits the largest percentage of CO_2 speeding up global warming and remaining a significant cause of climate change.

B. Effects of Climate Change :

i. Extreme Weather :

1. Changes to weather are perhaps the most noticeable effect of climate change for the average person.

2. Extreme weather influenced by climate change includes stronger storms and hurricanes, heat waves, wildfires, more flooding, heavier droughts, etc.

ii. Health : Climate change related health risks may include :

1. Injuries and fatalities from severe weather.
2. Asthma and cardiovascular disease from air pollution.
3. Respiratory problems from increased allergens.
4. Diseases from poor water quality.

iii. Negative Impact on Ecosystem :

1. Ecosystems are interconnected webs of living organisms that help support all kinds of plant and biological life.
2. Climate change is already changing seasonal weather patterns and disrupting food distribution for plants and animals throughout the world, nearly 30 % of plant and animal species are at risk of extinction if global temperatures continue to rise.

iv. Rising Sea Level :

1. Rising sea levels could have far reaching effects on coastal cities and habitats. Increasing ocean temperatures and melting ice sheets have steadily contributed to the rise of sea levels on a global scale.
2. It will causing increased flooding and decrease in ocean and wetland habitats.

v. Shrinking Ice Sheets :

1. While contributing to rising sea levels, shrinking ice sheets present their own set of unique problems, including increased global temperatures and greenhouse gas emissions.

PART-4

Energy Storage.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.7. What do you understand by energy storage ?

Answer

1. Energy storage systems are essential to the operation of power systems.
2. They ensure continuity of energy supply and improve the reliability of the system.

3. Energy storage systems can be in many forms and sizes. The size, cost, and scalability of an energy storage system highly depend on the form of the stored energy.
4. Energy can be stored as potential, kinetic, chemical, electromagnetic, thermal, etc.
5. Some energy storage forms are better suited for small scale systems and some are used only for large scale storage systems.
6. For example, chemical batteries are well suited for small systems ranging from watches and computers to building backup systems.
7. Pumped hydropower storage, on the other hand, which stores huge amounts of energy in the form of potential energy of water, can be found only in large power systems.

Que 5.8. Briefly explain the different types of storage systems.

AKTU 2019-20, Marks 10

Answer

Different types of storage systems are as follows :

i. Pumped Hydro Energy Storage System :

1. The operating principle of the pumped hydro storage uses the potential energy of water keep in a reservoir.
2. Water is pumped from lower reservoir to upper reservoir to store energy when the power demand is low.
3. When the power demand is high, water flows from upper reservoir to lower one, activates the turbine and generates electrical energy.
4. Stored energy capacity of this system is proportional to water volume of upper reservoir and height difference between the upper and lower reservoirs.
5. This energy storage technology is a large scale and long term energy storage system.

ii. Compressed Air Energy Storage System :

1. In this energy storage technology, conventional gas turbine technology is used. Energy is stored as compressed air in an underground storage chamber.
2. When the power demand is low, the air is pumped to chamber and excess energy is stored. The compressed air in the chamber is converted to the electrical energy via gas turbine.
3. The compressed air is heated and converted to the mechanical energy via a set of low and high pressure turbines.
4. Electrical generators coupled with turbines generate electrical energy.

5. The compressed air storage technology also has long life about 40 years and it is considered as long term storage technologies compatible and competitive with the pumped hydro energy storage systems.

iii. Battery Energy Storage System :

1. Batteries are the most common energy storage technologies.
2. The energy is stored in a battery cell as electrochemical energy.
3. The battery cells are connected in series or in parallel to reach the desired voltage, current and capacity values.
4. A battery cell composes two electrodes called anode and cathode, and the electrolyte.
5. Several types of the batteries are proposed. All types of batteries have different specifications, therefore, none of them is suitable for all kinds of applications.

iv. Flow Battery Energy Storage System :

1. Flow batteries which are a kind of rechargeable battery are relatively recent technology. In this system, there are two electrolyte liquids in separate tanks and an electrochemical cell is present.
2. In the electrochemical cell, a membrane is held between two electrodes. These electrolytes are pumped through the electrochemical cell and ion exchange occurs through the membrane.
3. Today, three types of flow batteries are commercially available in the market : the vanadium redox battery, the polysulphide bromide battery and the zinc bromine battery.

v. Hydrogen based Energy Storage System :

1. The hydrogen energy storage system consists of electrolyser, hydrogen storage, fuel cell and power conversion stage.
2. Hydrogen can be obtained via water electrolysis, and energy required for this action can be obtained from renewable energy sources or conventional energy sources.
3. The obtained hydrogen can be stored in metal or composite tanks as gas or metal hydrides.

PART-5

Energy Conservation, Engineering for Energy Conservation

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.9. **What do you understand by energy conservation ?**

Answer

1. Energy conservation refers to the methods of reduction in energy consumption by way of elimination of wastage and promotion of efficiency.
2. Energy conservation is the key element of energy management.
3. We can reduce the energy consumption by adopting various ways of energy conservation which includes efficient use of technologies and avoiding energy wastages.
4. The various principles involved in energy conservations are :
   i. Optimal control,
   ii. Optimize capacity,
   iii. Optimize load,
   iv. Use efficient processes,
   v. Reduce losses,
   vi. Energy containment,
   vii. Examine energy conservation opportunities, and
   viii. Energy storage facilities.

Que 5.10. **Write a short note on energy engineering.**

Answer

1. Energy engineering or energy systems engineering is a broad field of engineering dealing with energy efficiency, energy services, facility management, plant engineering, environmental compliance, sustainable energy and renewable energy technologies.
2. Energy engineering combines knowledge from the fields of physics, math, and chemistry with economic and environmental engineering practices.
3. Energy engineering is increasingly seen as a major step forward in meeting carbon reduction targets.
4. Energy minimization is the main purpose of this growing discipline. Often applied to building design, heavy consideration is given to HVAC (Heating ventilation and air conditioning), lighting, refrigeration, to both reduce energy loads and increase efficiency of current systems.

Que 5.11. **What are the key responsibilities of an energy engineer ?**

Answer

Key responsibilities of an energy engineer are as follows :

1. Identifying the area of high energy consuming sources and designing and developing energy efficient processes in such areas.
2. Introducing innovative energy efficient processes and implementing the same in the organization for high energy efficiency.
3. Conducting on site and field observations, collecting energy efficiency data, and analyzing the process of energy efficiency used.
4. Evaluating energy efficiency by reviewing architectural, mechanical, and electrical plans of the organization, consulting the engineers for installation of energy efficient systems like climate control systems, day lighting design, etc., and preparing technical reports for implementation of energy efficient designing.
5. Taking pivotal role in creating awareness about energy efficient systems installed and actively participating in encouraging the use of alternative energy resources.
6. Managing the construction, designing, and development of energy management projects as per the guidelines from the federal department and the budget requirement, performing energy modelling, verification, and commissioning as per the large scale industrial process.
7. Coordinating with the project management team for overall analysis of energy management system installation.

PART-6

Concept of Green Buildings and Green Architecture.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.12. **What is green energy ? What are the benefits of green energy ?** **AKTU 2019-20, Marks 10**

Answer

A. Green Energy :

1. It is also known as renewable energy. It comes from natural sources such as sunlight, wind, rain, tides, plants, algae and geothermal heat.

2. Green energy is a clean energy, this means that it is produced with little or no environmental impact and does not dispense greenhouse gases into the air that contribute to global warming.
3. Green energy can replace fossil fuels in all major areas of use including electricity, water and space heating and fuel for motor vehicles.
4. Types of green energy include solar energy, hydro power, wind energy, biomass, geothermal energy, tidal energy, etc.

B. Benefits of Green Energy :

1. Green energy is eco friendly.
2. It is a reliable source of energy.
3. It requires less maintenance.
4. Improved health conditions.
5. Green energy never runs out.

Que 5.13. Define green building. Also write down the features that makes a building green.

Answer

A. Green Building : A green building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.

B. Features of Green Building :

1. Efficient use of energy, water and other resources.
2. Use of renewable energy, such as solar energy.
3. Pollution and waste reduction measures, and the enabling of reuse and recycling.
4. Good indoor environmental air quality.
5. Use of materials that are non-toxic, ethical and sustainable.
6. Consideration of the environment in design, construction and operation.
7. Consideration of the quality of life of occupants in design, construction and operation.
8. A design that enables adaptation to a changing environment.

Que 5.14. What are the various elements of green building ?

Answer

Various elements of green building are as follows :

i. **Site Planning and Design :** Design our site to fit into the surroundings neighbourhood and to work with natural features to provide safe play

spaces, shade our building, and naturally control storm water runoff. Minimize site impacts by shrinking the physical footprint of your development with more compact building and parking lot layouts and by taking care of trees and soil conditions during construction.

ii. **Community :** Green buildings and developments support strong communities by giving neighbours places to meet, establishing a sense of place and safety, and creating spaces for pedestrians and kids, rather than cars.

iii. **Indoor Air Quality :** Achieving a high quality indoor environment requires careful design, construction, and materials choices, and thus strong coordination among the building team. Indoor air quality centers on well designed ventilation and moisture control, which goes hand in hand with energy efficiency and building durability.

iv. **Energy :** Energy efficiency is the key to making a building finely tuned, lean, green machine. Start using energy modelling software early in the design process to take advantage of the sun and wind to heat, light, and cool our building affordably.

v. **Materials :** Green, high quality building materials that minimize or eliminate indoor air quality concerns, avoid toxics, and greatly reduce waste are used in green buildings.

vi. **Waste :** Reduce, reuse, and recycle construction and demolition waste to cut costs and improve building quality. Design for efficient use of materials and for durability, avoiding future waste.

vii. **Water :** Conserve finite freshwater resources and reduce utility bills by installing water efficient appliances and plumbing fixtures, landscaping with drought resistant plants and efficient irrigation, and putting rainwater and greywater to use.

Que 5.15. Discuss about green architecture in detail.

Answer

1. Green architecture is a sustainable method of green building design. It includes both design and construction keeping the environment in mind.
2. Green architects generally work with the key concepts of creating an energy efficient, eco-friendly house.
3. It is both the design and the construction which can make a building truly sustainable and green, and the architect should pay careful attention to both aspects of the entire process.
4. Green architecture can be wonderful examples of the possibility of humans living harmoniously within the environment.
5. The opportunities exist to design beautiful, energy efficient and eco-friendly residences and workplaces that demonstrate our human ability to adapt to and peacefully live within the ecology of the natural world.

6. The natural ecology of the planet should be the macro model for architects to use as a model for a green building.
7. Architecture can model itself on the planetary system to copy the natural green environment, making a new building, or adapting an existing building, both eco-friendly, in terms of materials used and the space it occupies, and energy efficient, including solar technology.

PART-7

LEED *Ratings.*

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.16. **What do you understand by LEED ?**

Answer

1. LEED (Leadership in Energy and Environmental Design) is an internationally recognized green building certification system, providing third party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most : energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and sensitivity to their impacts.
2. LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions.
3. It works throughout the building lifecycle - design and construction, operations and maintenance, and significant retrofit.
4. LEED provides a sustainability framework for design, construction, operations, and maintenance of new and existing buildings.
5. LEED provides a point system to score green building design and construction.
6. The system is categorized in five basic areas : sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality.

Que 5.17. **Write down the four levels of LEED ratings.**

Answer

Four levels of LEED rating are as follows :

1. LEED certified : 40 – 49 points
2. Silver level : 50 – 59 points
3. Gold level : 60 – 79 points
4. Platinum level : 80 + points

PART-8

Identification of Energy Related Enterprises that Represent the Breath of the Industry and Prioritizing these as Candidates.

CONCEPT OUTLINE

Various Energy Related Enterprises

1. Fossil fuels industries,
2. Nuclear power industries,
3. Renewable energy industry, and
4. Traditional energy industry.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.18. **What do you mean by energy related enterprises ?**

Answer

1. The energy enterprise is the totality of all of the industries involved in the production and sale of energy, including fuel extraction, manufacturing, refining and distribution.
2. Modern society consumes large amounts of fuel, and the energy industry is a crucial part of the infrastructure and maintenance of society in almost all countries.
3. In particular, the energy enterprise comprises :
   i. The fossil fuel industries, which include petroleum industries (oil companies, petroleum refiners, fuel transport and end user sales at gas stations), coal industries (extraction and processing) and the natural gas industries (natural gas extraction, and coal gas manufacture, as well as distribution and sales),

ii. The electrical power industry, including electricity generation, electric power distribution and sales,

iii. The nuclear power industry,

iv. The renewable energy industry, comprising alternative energy and sustainable energy companies, including hydroelectric power, wind power, and solar power generation, and the manufacture, distribution and sale of alternative fuels, and

v. Traditional energy industry based on the collection and distribution of firewood, the use of which, for cooking and heating, is particularly common in poorer countries.

PART-9

Embodied Energy Analysis and Use as a Tool for Measuring Sustainability.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.19. What do you mean by embodied energy ?

Answer

1. Embodied energy is the total energy required for the extraction, processing, manufacture and delivery of building materials to the building site.
2. Unlike the life cycle assessment, which evaluates all of the impacts over the whole life of a material or element, embodied energy only considers the front end aspect of the impact of a building material. It does not include the operation or disposal of materials.
3. Embodied energy must be considered over the lifespan of a building, and in many situations, a higher embodied energy building material or system may be justified because it reduces the operating energy requirements of the building.
4. Embodied energy is measured as the quantity of non-renewable energy per unit of building material, component or system.
5. The total amount of embodied energy may account for 20 % of the building's energy use, so reducing embodied energy can significantly reduce the overall environmental impact of the building.
6. Buildings should be designed and materials selected to balance embodied energy with factors such as climate, availability of materials and transport costs.

7. When selecting building materials, the embodied energy should be considered with respect to :
   i. The durability of building materials,
   ii. How easily materials can be separated,
   iii. Use of locally sourced materials,
   iv. Use of recycled materials,
   v. Specifying standard sizes of materials,
   vi. Avoiding waste, and
   vii. Selecting materials that are manufactured using renewable energy sources.

Que 5.20. What is the meaning and importance of embodied energy analysis as a measure of sustainability and why we need to develop widely accepted standards for embodied energy ?

Answer

1. While comparing products or services we look at the feature set, quality, compare the price, etc.
2. Now if we are concerned about sustainability, it is also important to look at the impact that the product or service has over its entire life cycle *i.e.*, from mine to manufacture to market and to end of service life.
3. In other words to look at a given product or service and trace its impacts over its expected service life and the recoverability of the materials that go together to comprise it. This is known as the sustainability view of a product or service.
4. Coming up with the embodied energy analysis is not an exact science, but it usually include the energy used throughout the entire production value chain *i.e.*, from resource acquisition to final packaging and distribution.
5. Embodied energy analysis is valuable and comparing embodied energy content of two products or services can help decision makers and consumers evaluate and compare products or services. This brings us to the need for standards.
6. A fair number of energy efficiency ratings have been created to measure and rate the relative energy consumption of products and provide a consumer friendly ranking system, so energy efficient products can use it to promote their energy efficiency.

PART-10

Energy Audit of Facilities and Optimization of Energy Consumption.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.21. What is energy audit ?

Answer

1. Energy audit is an examination for energy efficiency improvement through analysis of energy usage.
2. It uncovers energy savings opportunities which are assessed to identify savings.
3. A general audit is a comprehensive evaluation of potential energy conservation measures through detailed information collection, in depth interviews with facilities or operations managers and the analysis of energy profiles created through interval metering.

Que 5.22. What are the aims or objectives of energy audit ?

Answer

The objectives of energy audit are as follows :

1. To understand the facility's energetic behaviour.
2. To identify the excess of energy consumed.
3. To find out the motive of this excess.
4. To propose alternate solutions.
5. To justify them from technical and economical point of view.
6. To determine the ideal energy consumption profiles.

Que 5.23. Discuss in detail the various types of energy audit.

Answer

Types of energy audit are as follows :

a. Envelope Audit : It surveys the building or factory envelope to determine the energy losses for leakage, construction problems, openings, doors and windows defects, lack of insulation, etc.

b. Functional Audit :

1. It surveys the quantity of energy used for each function such as :
   - i. Heating systems,
   - ii. Ventilation and air conditioning systems,
   - iii. Building,

   - iv. Lighting,
   - v. Hot water supply, and
   - vi. Air distribution.
2. This audit also identifies the energy conservation opportunities in each of these areas.

c. Process Audit :

1. It surveys the quantity of energy required for each process such as :
   - i. Department-wise process plant and machinery,
   - ii. Heating process,
   - iii. Ventilation and air conditioning process, and
   - iv. Furnaces.
2. This audit also identifies the energy conservation opportunities in each process.

d. Transportation Audit :

1. It surveys the quantity of energy required for all types of transportation systems like vehicles, cars, trucks, and other material handling equipment in an industry.
2. It also identifies the energy conservation opportunities for such transportation systems.

e. Utility Audit :

1. It surveys the quantity of energy required from each utility or support service in an industry.

Que 5.24. Discuss about the optimization of energy consumption.

Answer

1. Although energy is critical to systems in the production domain, production planners have not been provided with the tools needed to integrate energy explicitly in their resource allocation models for overall production efficiency.
2. Optimum energy usage (OEU) will change this paradigm by enabling best practices in energy resource allocation by providing visibility to energy data throughout the layers of the production domain.
3. Realization of OEU requires three approaches to typical use cases for the industrial consumers which are discussed as given below :

i. Awareness of Energy Usage :

1. Energy awareness is the foundation of OEU. It drives fundamental behavioural changes across all layers of the production domain.

This is the subtitle of PDF, Use long text here.

2. Starting with simple and often free or low cost actions to reduce energy consumption, energy awareness works itself into the fiber of the corporate culture.
3. Production planners will start including energy requirements into production bills of material.

ii. Efficient Consumption of Energy :

1. Efficient energy consumption is the accelerant for OEU.
2. By leveraging automation and manufacturing execution systems, industrial consumers can consolidate energy information in order to match overall power consumption levels and timing with specific production requirements.
3. Energy monitoring and management promote efficient consumption and multiply the benefits of energy awareness by automating actions that reduce energy consumption.

iii. Transacting Energy for the Best Result :

1. Transacting energy for the best result is the integrator for OEU.
2. By leveraging asset management and internal facility and process energy delivery systems, the industrial consumer can interface with the power grid domain to procure and exchange energy for the best result.

☺☺☺

Energy and its Usage (2 Marks Questions)

1.1. What is energy ? AKTU 2019-20, Marks 02

Ans: Energy is defined as the capacity to exert a force through a distance. It exists in various forms like heat energy, chemical energy, nuclear energy, mechanical energy, etc.

1.2. Write down various units of energy.

Ans: Various units of energy are as follows :
1. Joule,
2. Calorie, and
3. kWh.

1.3. Define thermal energy reservoir.

Ans: Thermal energy reservoir is defined as a large body of infinite heat capacity, which is capable of absorbing or rejecting an unlimited quantity of heat without suffering appreciable changes in its temperature.

1.4. What is meant by heat engine cycle and heat engine ? What is its function ?

Ans: **Heat Engine Cycle and Heat Engine :** A heat engine cycle is a thermodynamic cycle in which there is a net heat transfer to the system and a net work transfer from the system. The system which executes a heat engine cycle is called a heat engine.
Function : The function of a heat engine cycle is to produce work continuously at the expense of heat input to the system.

1.5. Define heat pump.

Ans: Heat pump is a device which, operating in a cycle, maintains a body at a temperature higher than the temperature of the surroundings.

1.6. What do you mean by refrigerator ?

This is the subtitle of PDF, Use long text here.

Ans: Refrigerator is a device which, operating in a cycle, maintains a body at a temperature lower than the temperature of the surroundings.

1.7. Define coefficient of performance.

Ans: Coefficient of performance is defined as the ratio of desired effect to the work done.

1.8. What do you mean by Carnot cycle ?

Ans: Carnot cycle is an ideal hypothetical cycle in which all the processes constituting the cycle are reversible.

1.9. State Carnot theorem.

Ans: Carnot theorem states that all heat engines operating between a given constant temperature source and a given constant temperature sink, none has a higher efficiency than a reversible engine.

1.10. Define entropy ? **AKTU 2019-20, Marks 02**

Ans: Entropy is defined as the quantitative measure of disorder or randomness in a system. It deals with the transfer of heat energy within a system.

1.11. What do you mean by entropy principle ?

Ans: According to this principle, the entropy of an isolated system can never decrease. It always increases and remains constant only when the process is reversible.
Mathematically,

$$ds_{iso} \geq 0$$

1.12. Classify the IC engines on the basis of cycle of operation.

Ans: On the basis of cycle of operation, IC engines are classified into two categories :

1. Constant volume heat addition cycle engine or Otto cycle engine.
2. Constant pressure heat addition cycle engine or diesel cycle engine.

1.13. Write the applications of open cycle gas turbine.

Ans: Applications of open cycle gas turbine are as follows :

1. In aircraft,
2. In marine,
3. In power generation.
4. In locomotive,
5. In automobile, and

1.14. Why Stirling engines are not used ?

AKTU 2019-20, Marks 02

Ans: Stirling engines are not used because the engine requires some time to warm up before it can produce useful power and it cannot change its power output quickly.

1.15. Define supercapacitor.

Ans: Supercapacitor is a high capacity capacitor with a capacitance value much higher than other capacitors.

1.16. What is fuel cell ?

Ans: A fuel cell is an electrochemical device that converts the chemical energy of a fuel into electricity.

1.17. Define phase change.

Ans: Phase change process is the change of material physical state from one state to another like solid to liquid and vice-versa.

☺☺☺

This is the subtitle of PDF, Use long text here.

2 UNIT

Nuclear Energy (2 Marks Questions)

2.1. Write down the various fundamental forces of nature.

Ans: Fundamental forces of nature are as follows :

1. Gravitational forces,
2. Weak nuclear forces,
3. Electromagnetic forces, and
4. Strong nuclear forces.

2.2. Define nuclear forces.

Ans: Nuclear forces are the forces which act between two or more nucleons. They bind protons and neutrons into atomic nuclei.

2.3. What is the binding energy ?

Ans: Binding energy is defined as the energy required to overcome the binding forces of nucleus.

2.4. What do you mean by activity ?

Ans: Activity is defined as the intensity of emitted radiation. This is directly dependent on the rate of disintegration of the element.

2.5. What do you mean by half life ?

Ans: Half life represents the rate of decay of the radioactive isotopes. It is the time required for half of the parent nuclei to decay or to disintegrate.

2.6. What is average (mean) life ?

Ans: Average life indicates the average of total time for which the radioactive nuclei has disintegrated for several half lives.

2.7. What is a chain reaction ?

Ans: Chain reaction is the process in which the number of neutrons keeps on multiplying rapidly (in geometrical progression) during fission till whole of the fissionable material is disintegrated.

2.8. What do you mean by nuclear fusion ?

Ans: Nuclear fusion is a reaction in which two or more atomic nuclei are combined to form one or more different atomic nuclei and subatomic particles (neutrons or protons).

2.9. What are the moderators ?

Ans: Moderator is a material used to slow down the neutrons from high kinetic energy.

2.10. Define thermal neutron.

Ans: Thermal neutron is a free neutron that has an average energy of motion corresponding to the average energy of the particles of the ambient materials.

2.11. What do you mean by nuclear fission ?

Ans: Nuclear fission is defined as a type of nuclear disintegration in which heavy nucleus splits up into two nuclei of nearly comparable masses with liberation of energy.

2.12. What do you mean by pressurized water reactor (PWR) ?

Ans: Pressurized water reactor is a light water cooled and moderated thermal reactor having an unusual core design, using both natural and highly enriched fuel.

2.13. What is a boiling water reactor (BWR) ?

Ans: In a boiling water reactor enrich fuel is used. In this the steam flowing to the turbine is produced directly in the reactor core.

2.14. Define binding energy curve.

Ans: The graphical relationship between binding energy per nucleon and mass number is called binding energy curve.

☺☺☺

3 UNIT

Solar Energy (2 Marks Questions)

3.1. What do you mean by solar energy ?

Ans: Solar energy is a clean, cheap and abundantly available renewable energy and it is also the most important of the non-conventional sources of energy because it is non-polluting and therefore helps in decreasing the green house effect.

3.2. Define solar cell.

Ans: Solar cells are energy conversion devices which are used to convert sunlight to electricity by the use of the photovoltaic effect.

3.3. Write down the applications of solar energy.

Ans: Applications of solar energy are as follows :
1. Solar water heating,
2. Solar distillation,
3. Solar pumping,
4. Solar electric power generation, and
5. Solar thermal power production.

3.4. Write down the disadvantages of solar energy.

Ans: Disadvantages of solar energy are as follows :
1. High capital cost due to requirement of large area.
2. Limited to sun shine hours.
3. Need of tracking due to change in position of sun.
4. There is a need of storage.

3.5. What are the materials used in solar cells ?

Ans: Solar cell materials are $CuInSe_2$, CaS, Cd-Te, Cu_2S, InP, GaAs, Zinc Telluride (ZnTe), AlSb (Aluminium antimonide). Silicon is the most commonly used material for solar cell.

3.6. What do you understand by maximum efficiency of solar cells ?

Ans: Maximum efficiency of solar cell is defined as the ratio of maximum electric power output to the incident solar radiation.

3.7. What are the different types of solar radiation ?

Ans: Different types of solar radiations are as follows :
1. Extraterrestrial solar radiations, and
2. Terrestrial solar radiations.

3.8. What are the different devices used for measuring the solar radiations ?

Ans: Devices used for measuring the solar radiations are as follows :
1. Pyranometer,
2. Pyrheliometer, and
3. Sunshine recorder.

3.9. Define solar constant.

Ans: The rate at which solar radiation strikes at the top of the atmosphere is called the solar constant.

3.10. What do you mean by beam radiation ?

Ans: Solar radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called direct radiation or beam radiation.

3.11. Define irradiance and albedo.

Ans: **Irradiance :** The rate of incident energy per unit area of a surface is known as irradiance.
Albedo : The earth reflects back nearly 30 % of the total solar radiant energy to the space by reflection from clouds, by scattering and by reflection at the earth's surface. This is known as albedo.

3.12. Define semiconductors. **AKTU 2019-20, Marks 02**

Ans: A semiconductor is a material whose electrical conductivity lies between conductor and an insulator.

3.13. What are the different types of semiconductors ?

Ans: Different types of semiconductors are as follows :
Intrinsic Semiconductor : These are pure non-metallic materials, such as germanium and silicon.
Extrinsic Semiconductor : The intrinsic material when added with impurity is called extrinsic semiconductor.

3.14. How holes are produced in semiconductors ? **AKTU 2019-20, Marks 02**

Ans: Holes are produced when electrons in atoms move out of the valance band into the conduction band, which happens everywhere in a semiconductor.

This is the subtitle of PDF, Use long text here.

3.15. Explain attenuation of solar radiation.

AKTU 2019-20, Marks 02

Ans: Attenuation of solar radiation means scattering of radiation as it passes through the atmosphere and it is caused by interaction of radiation with air molecules, water and dust.

3.16. What is the principle of solar cell ?

AKTU 2019-20, Marks 02

Ans: Solar cell works on the principle of conversion of solar energy into electricity by photovoltaic effect.

☺☺☺

Conventional and Non-Conventional Energy Sources (2 Marks Questions)

4.1. What are primary energy resources ?

Ans: The resources obtained from the environment are known as primary energy resources.
Example : Fossil fuels, Solar energy, Hydro energy, and Tidal energy.

4.2. What are secondary energy resources ?

Ans: The resources that do not occur in nature but are derived from primary energy resources are known as secondary energy resources.
Example : Electrical energy from coal burning, H_2 obtained from hydrolysis of H_2O, etc.

4.3. Define wind energy.

Ans: The wind energy, which is an indirect source of energy, can be used to run a wind mill which in turn drives a generator to produce electricity.

4.4. What are the advantages of wind energy ?

Ans: Advantages of wind energy are as follows :
1. It is renewable and available at free of cost.
2. Low operating cost.
3. Economically competitive.
4. It is reliable and cost effective for large unit.

4.5. What is the basic principle of wind energy conversion ?

Ans: The basic principle of wind energy is to convert the kinetic energy of wind into more useful forms like mechanical power and electrical power.

4.6. Define the continuity equation.

Ans: The equation based on the principle of conservation of mass is called continuity equation.

4.7. State the Bernoulli's theorem.

Ans: Bernoulli's theorem states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant.

4.8. Define viscosity.

Ans: Viscosity may be defined as the property of a fluid which determines its resistance to shearing stresses. It is a measure of the internal fluid friction which causes resistance to flow.

4.9. Define wind farms.

Ans: The wind farms are open spaces away from forest, cities and mountains so that average annual wind speed should not be less than 7 m/s and not away from the distribution centre.

4.10. Explain the drag and lift.

Ans: **Drag :** The component of the total force (F_R) in the direction of motion is called drag. This component is denoted by F_D.
Lift : The component of the total force (F_R) in the direction perpendicular to the direction of motion is known as lift. This is denoted by F_L.

4.11. Give the sources of geothermal energy.

AKTU 2019-20, Marks 02

Ans: Sources of geothermal energy are as follows :
1. Hydrothermal energy sources,
2. Vapour dominated sources,
3. Hot dry rock sources,
4. Geopressured sources, and
5. Magma sources.

4.12. Define ocean thermal energy conversion.

Ans: Ocean thermal energy conversion (OTEC) is a means of converting ocean thermal energy into useful energy. OTEC is a technology that converts solar radiation into electric energy.

4.13. How tides are generated ? **AKTU 2019-20, Marks 02**

Ans: Tides are generated by the action of gravitational forces of the sun and the moon in the ocean, by the spinning of the earth about its axis and the relative positions of the earth, moon and the sun.

4.14. Write the name of devices used for wave energy conversion.

Ans: Devices used for wave energy conversion are as follows :
1. Hose pump,
2. Pelamis, and
3. Oscillating water column device.

4.15. Define hydropower.

Ans: Hydropower is the power derived from the energy of falling or fast running water which may be harnessed for useful purpose.

4.16. What are the main components of wind energy conversion system (WECS) ?

Ans: The main components of wind energy conversion system are as follows :
1. Rotor with blade,
2. Electromagnetic brakes,
3. Controller,
4. Mechanical brakes,
5. Gear box,
6. Generator,
7. Shaft, and
8. Flap or tail vane.

Systems and Synthesis (2 Marks Questions)

5.1. Define nuclear radiation.

Ans: Nuclear radiation refers to the particles and photons emitted during reactions that involve the nucleus of the atom.

5.2. What are the different types of nuclear radiation ?

Ans: Different types of nuclear radiation are as follows :
1. Alpha rays,
2. Beta rays,
3. Gamma rays, and
4. *X*-rays.

5.3. What do you understand by nuclear waste ?

Ans: Radioactive by products resulting from fusion, fission, refinement or processing of radioactive materials are known as nuclear waste.

5.4. Write down the name of some nuclear waste disposal methods.

Ans: Some nuclear waste disposal methods are as follows :
1. Geological disposal,
2. Reprocessing,
3. Transmutation, and
4. Space disposal.

5.5. What are the various factors affecting climate change ?

Ans: Factors affecting climate change are as follows :
1. Latitude,
2. Altitude or height from sea level,
3. Direction of wind,
4. Ocean currents, and
5. Forest.

5.6. Define energy conservation. **AKTU 2019-20, Marks 02**

Ans: Energy conservation refers to the methods of reduction in energy consumption by way of elimination of wastage and promotion of efficiency.

5.7. Classify various types of energy storage systems.

Ans: Various types of energy storage systems are :
1. Pumped hydro energy storage,
2. Compressed air energy storage,

3. Battery storage energy system,
4. Flow battery energy storage system, and
5. Hydrogen based energy storage system.

5.8. Write down the disadvantages of green energy.

Ans: Disadvantages of green energy are as follows :
1. High installation cost.
2. Renewable energy often relies on the weather for its source of power.

5.9. What are the seven principles of green architecture ?

Ans: The seven principles of green architecture are as follows :
1. Site and its surroundings,
2. Energy efficiency,
3. Water efficiency,
4. Material efficiency,
5. Indoor air quality,
6. Waste reduction, and
7. Low maintenance costs.

5.10. What is LEED certification ?

Ans: LEED certification process is a program for designing and building energy efficient and water conserving buildings for which construction will be used green and sustainable materials and resources.

5.11. Name some energy related enterprises.

Ans: Some energy related enterprises are as follows :
1. Fossil fuels industry,
2. Nuclear power industry, and
3. Renewable energy industry.

5.12. Define embodied energy.

Ans: Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport and product delivery.

5.13. Write down the sources of nuclear waste.

Ans: Following are the sources of nuclear waste :
1. Nuclear fuel cycle,
2. Legacy waste,
3. Medicine, and
4. Industry.

5.14. What is green energy ?

Ans: Green energy is a clean energy, this means that it is produced with little or no environmental impact and does not dispense greenhouse gases into the air that contribute to global warming.

5.15. What is energy audit ?

Ans: Energy audit is an examination for energy efficiency improvement through analysis of energy usage. It uncovers energy savings opportunities which are assessed to identify savings.

☺☺☺

This is the subtitle of PDF, Use long text here.

Ans: Refer Q. 3.10, Page 3–11G, Unit-3.

6. Attempt any **one** part of the following : (10 × 1 = 10)

a. How tidal power plants are classified and what are the limitations of tidal power plant ?

Ans: Refer Q. 4.22, Page 4–23G, Unit-4.

b. What are conventional and non-conventional energy sources ? Write short notes on classification of energy sources.

Ans: Refer Q. 4.3, Page 4–5G, Unit-4.

7. Attempt any **one** part of the following : (10 × 1 = 10)

a. What is green energy ? What are the benefits of green energy ?

Ans: Refer Q. 5.12, Page 5–12G, Unit-5.

b. Briefly explain the different types of storage systems.

Ans: Refer Q. 5.8, Page 5–9G, Unit-5.

This is the subtitle of PDF, Use long text here.