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MAINS HACKER

NANOTECHNOLOGY

THE SCIENCE OF SMALL

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DIRECTOR'S MESSAGE

"Civil Service is not just a job; it is an opportunity, to do your bit for society and to contribute to nation-building. It is an opportunity to realise your potential and make a meaningful contribution in the emancipation of masses."

Mr. Dilip Kumar
Director, Vajirao IAS Academy

Good Civil Servants ensure efficient and smooth governance. They are the backbone of the country and they have the power to make a difference in people's life.

We have set up extremely tough targets for ourselves. Now a day's, most of the students are well aware and focused about their aim. They just need a streak of guidance. We feel that we have done our bit in providing that blue streak of guidance and we are honoured to be a reason of smile on certain lips, proud to be your teacher, friend and guide.

PREFACE

Science and Technology has an important role in the examinations conducted by the Union Public Service Commission and State Public Service Commissions. It is necessary for the aspirants to have knowledge of relevant and updated information on issues of national and international importance related to this field. Mains Hacker Series is being presented to the students to fulfil this requirement to clear and secure the mains. Preparation of the civil services exam is only completed when the aspirants have holistic knowledge and analysis of the dynamic nature of the various angles of the subject. Keeping this vision and approach and understanding the multidimensional need of students at the content level, these magazines will present current affairs, its basic static portion with relevant issues of general studies. Keeping in mind the mains exam, current articles burning issues, Ethics Case Studies, Biographies of important and eminent personalities, coverage of most useful topics of various important sections of General Studies and the most important current affairs issues are being covered under this series.

Khyati Khare

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1. What is Nanotechnology?

Nanotechnology is the basic understanding and full control of matter at the nanoscale, at dimensions which range between approximately 1 and 100 nanometers, where unique events enable novel applications.

It is made up of nanoscale science, engineering, and technology fields. It involves imaging, measuring, modelling, and manipulating of matter at this nano length scale.

Matter such as gases, liquids, and solids can express unusual physical, chemical, and biological properties and tendency at the nanoscale, differing in important ways from the properties of heavy materials and single atoms or molecules.

Some nanostructured materials and atoms are stronger or have different magnetic properties compared to other forms or sizes of the same material or atoms. Others are good at conducting heat or electricity. They may become more chemically reactive or reflect or exhibit light better or change colour as their size or structure is altered.

One nanometer is equal to a billionth of a metre or 10-9 of a metre.

2. Birth of Nanotechnology

The ideas and concepts behind nanoscience and nanotechnology started with a talk entitled “there is plenty of room at the bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a process in which scientists would be able to manipulate and control individual atoms and molecules.

Richard Feynman is considered the father of nanotechnology.

The most important property that renders nanomaterials useful in a wide range of applications is the high surface-to-volume ratio. This one property alone has given the wide variety of applications of nanotechnology.

3. Types of Nanotechnology

The different types of nanotechnology can be classified according to how they work(top-down or bottom-up) and the medium in which they perform work (dry or wet):

Descending (top-down): Under these technology mechanisms and structures are miniaturised at the nanometric scale — from one to hundred nanometres in size. It is the most frequent up to date, especially in electronics.

Ascending (bottom-up): It starts with a nanometric composition — a molecule, for example — and through a mounting or self-assembly process it can create a larger mechanism than the one it has been started with.

Dry nanotechnology : It is applied to create structures in coal, silicon, and other inorganic materials, metals and semiconductors that do not perform with humidity.

Wet nanotechnology: It is applied on biological systems present in an drenched environment — including genetic material, membranes, enzymes and other cellular factors

4. Application of Nanotechnology

Nanotechnology and nanomaterials can be used in all kinds of industrial sectors and the manufacturing sector. They are usually found in following areas:

Electronics

Carbon nanotubes are very close in restoring silicon as a material for creating smaller, faster and more structured microchips and devices, as well as lighter and thin, more accompanying and stronger plus heavier quantum nanowires. Graphene's properties make it an ideal and suitable candidate for the development of flexible touchscreens.

Energy

A new semiconductor manufactured by Kyoto University makes it possible to create solar panels that multiply the amount of sunlight converted into electricity. Nanotechnology also helps in lowering the costs, produces stronger and lighter wind turbines and improves fuel efficiency and thermal insulation in some of the nanocomponents, and can save energy.

Biomedicine

The properties of some nanomaterials make them very ideal for improvisation in early diagnosis and treatment of neurodegenerative diseases or cancer. They are able to attack and destroy cancer cells selectively without harming other healthy cells of the human body. Some nanoparticles have also been used to enhance and increase pharmaceutical products such as sunscreen.

Environment

Air purification with the help of ions, wastewater purification with help of nanobubbles or nanofiltration systems for heavy metals are some of its environmentally-friendly applications in daily life. Nanocatalysts are also available to make chemical reactions more efficient, eco friendly and less polluting.

Food

In this field, nanobiosensors has been used to detect and inquire the presence of pathogens in food or other nanocomposites to improve food production by increasing mechanical and thermal resistance and decreasing oxygen transfer in packaged edible products.

Textile

Nanotechnology makes it possible and convenient to develop smart fabrics that don't stain or wrinkle easily , as well as stronger, lighter and more durable materials to make motorcycle helmets or sports equipment for day to day life.

5. Application of Nanotechnology in Health care

Nanomedicine

Nanomedicine uses nanotechnology in healthcare applications and utilities such as treatment and diagnostics of various diseases and symptoms using nanoparticles in medical devices, as well as nanoelectronic biosensors and other molecular nanotechnology. Nanomedicine is currently also being used to develop smart pills and for treating cancer.

Smart pills

The term 'smart pills' refers to nano-level or very very thin electronic devices that are shaped, modified and designed like pharmaceutical pills but perform more advanced functions such as sensing, imaging, and drug delivery.

Cancer detection and treatment

The main problem with regular chemotherapy and radiation is the damage caused to the body's healthy cells during its treatment. New nanomedicine applications are being used in the treatment of diseases like skin cancer, which enables efficient delivery of drugs and other therapeutic treatments and remedies to specific tumour sites and target cells with very low toxic side-effects.

Nanobots

Nanobots are micro-scale small size robots, which predominantly serve as miniature surgeons. They can be inserted to repair and replace intracellular structures of the human body. They are also replicating themselves to correct a deficiency in genetics or even eradicate diseases by replacing DNA molecules. This property is still under the developmental stage.

Nanobots are currently being tested to perform cataract surgery, through a microscopic needle inserted into the retina of the eye. Surgeons can direct this needle using a highly specialised magnetic field.

Nanobots can also be used to clear artery blockages(heart) by drilling through them. Scientists at Michigan State University and Stanford University together are developing nanobots which contain carbon nanotubes, loaded with a drug or medicine that can eat away arterial pathogens. This can reduce the risk of heart attacks.

Nanofibers

Nanofibers are being widely used in wound dressings and surgical textiles, as well as in implanting tissue culture and artificial organ components.

Scientists are also working on developing 'smart bandages', which when present on the site, will absorb into the tissue itself once the wound heals. Embedded nanofibres in these bandages contain clotting agents, antibiotics and even sensors also to detect signs of infection.

Nanotech-based wearables

The use of cloth-based nanotechnology in healthcare is a very new yet popular form of remote patient monitoring and guidance. Such wearables have embedded nanosensors in the cloth that can record medical data such as heartbeat, sweat components, and blood pressure in the human body. It helps in saving lives by alerting the wearer and medical professionals of any adverse changes faced by the human body.

6. Some other application of Nanotechnology

Carbon Nanotubes

Carbon nanotubes (CNTs) are looked at as cylindrical molecules that consist of rolled-up sheets of single-layer carbon atoms known as graphene. They can be single-walled (SWCNT) with a diameter of less than 1 nanometer (nm) or multi-walled (MWCNT), consisting of several concentrically interlinked nanotubes, with diameters reaching more than 100 nm(very thin). Their length can reach and breach several micrometres or even millimetres.

Applications:

- Used in electric wires to reduce and minimise losses
- It can replace silicon made and silicon applied transistors as they are very small and emit less heat and it can create revolution electronics.
- It can be used in solar cell.

Graphene

Graphene is a one-atom-thick sheet of carbon molecule,which is arranged in a honeycomb-like pattern. It is considered to be the world's thinnest, strongest as well as most conductive material – of both electricity and heat. All of these properties of these materials are exciting researchers and businesses around the globe – as graphene has the potential to create miracles in entire industries – in the fields of electricity, conductivity, energy generation, batteries, sensors and many more.

7. What are the risks of Nanotechnology?

- Nanotechnology may pose a potential risk to the environment, industry, health and other areas safety issues.
- Since this field is still at its nascent stage, the likely risks are contentious and yet to be identified.
- As for whether or not this technology requires special government regulation and control at large, the issue is still debated.
- The regulatory authorities such as the US Environmental Protection Agency and the Health and Consumer Protection Directorate of the European Commission have initiated assessing the potential risks posed by these nanoparticles.
- The organic food sector is the first in this field to be regulated so that the engineered and created nanoparticles are excluded from the organic produce. It has been implemented in Australia, UK and Canada as well as all the food certified agencies under the Demeter International Standards.
- Recently emerged Nanotoxicology is the study of potential health risks produced by nanomaterials.
- The human body can easily consume up the nanomaterials as they are very small in size.
- However, there is a need for detailed and analytical research on how it would behave inside of an organism. The behaviour of nanoparticles based on their size, shape, properties and surface reactivity must be thoroughly analysed and organised before launching them into the market.
- The nanomaterials that influence toxicology include chemical composition, shape, surface structure, surface charge, conductivity etc.
- Due to the numerous variables and points influencing the toxicology of the nanomaterials, it is difficult to generalise and provide the health risk associated with them.
- Thus, each new individual nanomaterial must be assessed,analysed and all material properties must be taken into consideration before its launch.
- Nanopollution is the generic and basic term that is used to describe the waste generated and created by the nanodevices or nanomaterials during the manufacturing procedure.
- Nano Wastes may create risk due to their small size and different properties and interactions. Since man-made nanoparticles are not naturally made or created, living organisms may not have the appropriate and suitable means to deal with them.
- The risk of nanotechnology on health, environment, society, economy,manufacturing, security, and trade is not yet fully assessed and analysed. This in itself is a threat.

8. Initiatives taken by the government

Nano Mission:

- It is an umbrella programme which aims for the overall and holistic development of research in the field of nanotechnology and to make use of its applied potential for economic growth and development.
- It works to promote basic research through funding to individuals or groups of scientists and create centres for excellence for promoting skills and education in this field.
- Infrastructure development is essential in this developing field and requires expensive and costly equipment like Optical Tweezers, Nano Indenter, Transmission Electron Microscope (TEM), Atomic Force Microscope (AFM) and many more. For the optimum use and exploitation of these expensive infrastructures and technologies, it has proposed and asked to establish a nationwide chain of shared facilities and applications.
- The promotion of application-oriented research and development projects in this area.
- It has also proposed the establishment of Nano Applications and Technology Development Centres, Nanotechnology Business Incubators in the country wide area etc.
- It is also promoting and accelerating the involvement and the engagement of the industrial sector into nanotechnology research and development either directly or through Public-Private Partnership ventures and initiatives.
- The Nano Mission is also focusing on providing education and training in diversified disciplines and areas to ensure the promotion of interdisciplinary culture in this area.
- International collaborations under this mission is allowing for visits of scientists and organisations from other countries and joint workshops, conferences, research projects with other nations should be organised. It also ensures access to high-end research facilities in other countries and the establishment of joint centres for excellence can be created. It also forges academia-industry partnerships at the international level when necessary.

Nanotechnology Initiative Programme

- It comes under the ambit of the Department of Information Technology.
- It was started in 2004 with great emphasis on nano-electronics materials.
- It is focusing on building the institutional capacity, eligibility and infrastructure for research and development and human resource development and initiative in the area of nano-electronics.
- The initiatives taken under this programme are as follows:
- The Centre of Excellence in Nanoelectronics was established at IIT Bombay and IISc Bangalore under government initiative. They are focusing more on healthcare and environmental monitoring, guiding and acoustic sensors, magnetic materials for LC development of organic and biopolymer devices,equipment for FRAMs and phase shifters etc.
- IIT Delhi has recently initiated a new project with an aim and goal to work on non-silicon based nanotechnology. The primary focus will be given to the nano-genetics field, nanophotonics, nano-photovoltaics, nanoelectronics, nanomechanics tools, biosensors, and mesoscale devices.
- Nanotechnology needs to measure nano dimensions, nano electrical properties and other fields Thus, standardisation facilities for electrical parameters like nanovolt, nanoscale current, nanoscale resistance, and nanoscale charges have been developed and established in the National Laboratory of government of India.

Nano Science and Technology Initiative (NSTI)

It was set up by the Department of Science and Technology (DST) in 2001 to focus on the issues which are related to infrastructure development, research and application programmes concentrated on nanomaterials including drugs, drug delivery, gene targeting and DNA chips.

UNNATI Program by ISRO

Unnati or Unispace Nanosatellite Assembly and Training is developed by ISRO is a capacity building program on nano-satellite development.

- ISRO's U.R Rao Satellite Centre at Bengaluru is conducting the program for the next 3 years starting from January 2019.
- It also will cooperate and help the participant countries to strengthen and institutionalise their capabilities in assembling, integrating, and testing nanosatellites.

9. Recent Development in Nanotechnology

- The Union Education Minister has recently launched the world's first Microsensor based and applied Explosive Trace Detector known as "NanoSniffer". The NanoSniffer was the creation of IIT Bombay incubated startup called NanoSniff Technologies. It is marketed and projected by the IIT Delhi incubated startup of Kritikal Solutions.The NanoSniffer can detect explosives in less than ten seconds.It can also detect all classes of military, homemade and conventional explosives.
- The Institute of Nano Science and Technology (INST) operating under the Department of Science and Technology has recently developed a nano-technology based low cost antiepileptic drug known as Rufinamide.
- A Bio Suit has been developed by the Defence Research and Development Organisation (DRDO) to keep the medical professionals working with COVID-19 safe and secure. The Organisation has used its expertise and knowledge in textiles, nanotechnology and coating to bring out the best product.
- Scientists from the Institute of Nano Science and Technology (INST), which is an autonomous institute under the Department of Science & Technology, have developed a material known as 'Hemostat'. It is a starch-based 'hemostat' developed to stop rapid blood loss during accidents etc, as it physically absorbs excess fluid and concentrates the natural clotting factors present in blood.

10. Way Forward

Nanotechnology has emerged as a growing and rapidly emerging field. It has great potential applications in many growing sectors and provides new opportunities. It is rapidly expanding its area of research with huge potential to revolutionise and develop human lives and to provide technological solutions to our problems in agriculture, energy, the environment and medicine. However, much is yet to be known and analysed about its impacts and risks. The government, before indulging in the promotion, creation and launch of this new technology, must invest and encourage more in the basic research to understand this new field.