Title:	Principles of Nanotechnology
Level:	**3**
Credit Value:	15

Learning outcomes *The learner will [‘know, understand or be able to do’ as a result of completing the unit]*	Assessment Criteria *The learner can [The means by which the achievement of the learning outcomes are measured and through which the unit grade is derived*
1. Understand the concept and history of nano-science	1.1 **Describe the developmental history of nanoscience** 1.2 **Explain the concept of nanoscience** 1.3 **Explain the application of nano-science for producing products currently and in the future**
2. Know the health & safety aspects of managing nanotechnology-based materials through their life cycle	**2.1 Describe the Rules & Regulations/ Directives that are applicable to the manufacturing of nano-technology-based products** **2.2 Describe a risk assessment for the manufacture of a given nano-based technology product** **2.3 Describe how to handle substances used to produce nanotechnology-based products safely** **2.4 Describe how to store substances used to produce nanotechnology-based products safely** **2.5 Describe how to dispose of substances used to produce nanotechnology-based products safely**
3. Understand the benefits of nano-based technologies	**3.1 Describe benefits of nanotechnology** **3.2 Explain how nanotechnology can enhance existing materials and surfaces** **3.3 Explain the different generations of nanotechnology** **3.4 Explain environmental benefits of nanotechnology**
4. Know commercially available nanotechnology -based products available in a given industry sector	**4.1 Explain the benefits of different nanotechnology -based products available in a given industry sector** **4.2 Explain how nanotechnology has enhanced these products**

Additional information about the unit	
Unit purpose and aim(s)	**This unit gives learners the opportunity to extend their knowledge of an area of science that is enabling new technologies in a given industry sector, their properties and applications.**
Unit expiry date	
Details of the relationship between the unit and relevant national occupational standards or other professional standards or curricula (if appropriate)	
Assessment requirements or guidance specified by a sector or regulatory body (if appropriate)	For learning outcome 1, learners must; • Be able differentiate between Nano-Science and Nanotechnology by clearly explaining the difference • Describe the history & development of Nano-Science and the unit of measurement used to measure nanoparticles • Explain the importance of Nanotechnology for the future and the environment, giving examples of Nano-based products that have had a major impacts in business or for individuals For learning outcome 2, learners must; • Explain the Rules & Regulations/ Directives applicable to the manufacturing, handling, storage and disposal of Nano-based products For learning outcome 3, learners must; • Explain the different generations of Nanotechnologies to date, giving examples. • Explain the benefits provided by Nanotechnologies for businesses, Individuals and the environment • Explain how some Nanotechnologies can enhance existing materials and surfaces, giving examples For learning outcome 4, learners must; • Give at least 2 practical examples of Nano-based technologies/ products available for a given industry sector • Explain how Nano-Science has enhanced these products and how they can benefit the given industry sector • Explain why you think the given industry sector should make use of these products. Are there any financial benefits to the industry in using these products

Support for the unit from a sector skills council or other appropriate body (if required)	
Location of the unit within the subject/sector classification system	
Name of the organisation submitting the unit	Pearson
Availability for use	
Unit available from	
Unit guided learning hours	**60**

Delivery and assessment guidance

This is a brief summary of any specific requirements necessary for the unit

Unit abstract

This unit provides learners with an introduction to the fundamental principles, scientific theory and history of Nano Science and Nanotechnologies.

Learners will gain an understanding of which rules and regulation/ directives are applicable to the manufacturing and handling of Nano-based materials & products.

Learners will gain an appreciation of the commercial applications of Nanotechnology in a given industry sectors and the benefits of Nano-based technologies

Unit content

- **Explain the concept and history of Nano-science**

  Nanoscience: definition; scientific principles; first use of the term "nanotechnology" (Norio Taniguchi, Tokyo, 1974): development of nanoscience; definitions (nanotechnology, nanoscale; unit of measurement); BSI PAS 71 and PAS 131 to136 provide definitions of all three terms plus other useful nanotechnology definitions for different sectors

  - Another useful definition describes nanotechnology as *"intentionally altering or manipulating materials or structures at the nanoscale (1nm to +/- 100nm) to give new properties. These novel properties at the nanoscale can frequently be harnessed to provide increased functionality and performance to materials and products"*. This definition has the advantage of conveying nanotechnology as a purposeful activity that seeks to achieve a useful result.

  Nanotechnologies: application of nano-science, commercial & environmental benefits and future impact

  - nanotechnology is an example of an "enabling technology" that can complement existing technologies by providing a huge range of new materials and products with enhanced and societally useful properties
  - can contribute to innovation in an incremental, ground breaking and sometimes "disruptive" way (description of a "disruptive technology" would also be useful here)
  - can contribute to greater efficiency of processes because of high reactivity of materials at the nanoscale
  - can contribute to a reduction in the use of some raw materials, e.g. cement
  - can contribute strongly towards greater sustainability and reduced environmental impact

  History: early theoretical predictions of the possibility of working at the nanoscale, e.g. Richard Feynmann *"There's Plenty of Room at the Bottom"* (1959)

- Eric Drexler *"Machines of Creation" (1986)* (Note. Some of the predictions therein also contributed to some later fears of potential uses/misuses of nanotechnology).

- **Explain the Health & Safety Aspects of managing Nanotechnology based materials through their life cycle**
- *Health & Safety*: safe storage and handling of Nano-based products; safe disposal of Nano-based products; industry guidelines for good practice and responsible care; where appropriate personal protective equipment and specific work guidelines

Rules & Regulations/directives; Regulations related to the manufacturing of Nano-based products

- sector-specific product legislation and Directives, e.g. Medicinal Products, Medical Devices, Construction Products, Food Safety, Packaging, REACH (chemicals), etc.
- Control of Substances Hazardous to Health (COSHH) Regulations
- Chemical Safety Data Sheets
- guidance in support of legislation
- EU and UK initiatives on responsible innovation
- manufacturers' instructions for use
- Safety Data Sheets
- applicable risk management procedures
- HSE guidance
- specific guidelines for hazardous materials (e.g. COSHH)
- manufacturers' instructions for use
- Safety Data Sheets
- specific risks at end-of-life or disposal (e.g. from lifecycle analysis or from product-specific regulations)
- recommendations for safe disposal, e.g. from manufacturers or Safety Data Sheets

- **Explain the benefits of nano-based technologies**

Benefits: different generations of Nanotechnology products; benefits of Nanotechnologies benefits of Nanotechnologies for businesses and individuals and the environment;

examples could include the following themes:

- improving performance/efficiency, e.g. insulating materials, coatings, etc.
- improving carbon footprint/environmental performance/use of energy
- decreasing the amount of the material required, e.g. cement and concrete, highly targeted drugs, etc.
- avoiding the use of hazardous or expensive materials, e.g. catalysts
- improving durability and life, e.g. diamond-like coatings, nano-treated textiles

Could include the following direct and indirect contributions:

- reduced use of materials, e.g. cement production accounts for some 5% of global CO_2 emissions. For example nano-silica-containing concrete can substantially reduce the use of such materials

- reduction in energy usage, e.g. nano-based insulation materials, low-heat transfer paints
- enhancement of sustainable energy-capturing systems, e.g. third generation photovoltaic cells, micro-scale wind and kinetic energy capture
- improvement to fuel cells, batteries and other energy storage systems
- remediation of contaminated sites and groundwater, e.g. through use of nano zero valent iron
- nano-membranes for water filtration and desalination systems
- nanomaterials and filters for CO_2 capture
- reduction in maintenance, e.g. self-cleaning glass and other surfaces
- nanomaterial additives to aid fuel efficiency
- reduction in the use of current hazardous materials
- treatments to improve the life of materials, e.g. nanoscale wood treatments and anti-corrosion coatings for metals
- pollution-reducing materials, e.g. building products that can photocatalyse nitrogen oxides in the urban environment

Enhancements: enhancing existing materials and surfaces with nano-based products *(specific examples should be chosen that are relevant to the sector the trainee is studying in)*

- examples could include the following themes:
- improvement in the efficiency of chemical processes due to small particle size, increased surface area available and greater reactivity
- reduction in the amounts of material needed due to greater reactivity
- more efficient products using less energy and resources
- highly-functionalised materials and surfaces, e.g. for use in membranes, as highly-specific detecting elements in sensors or biosensors, to impart additional functionality, e.g. self-cleaning or hard-wearing surfaces, etc.
- improvements to existing products, e.g. concrete, sunscreens, paints, cleaning agents, sports goods, packaging, medicines, etc.
- the development of novel classes of products, e.g. high-performance nano-composites, nano-foams and aerogels, phase-change materials, nanoscale drug carriers, etc.
- contributions towards environmental improvement and combating climate change, e.g. novel low-energy materials, energy capture (e.g. third generation flexible solar panels), printed electronics, low-power OLED lighting, etc.
- specific examples should be chosen that are relevant to the sector the trainee is studying in

- **Describe commercially available nano-based products available in a given industry sector**
  Products & Technologies: Nano-based technologies & products available for a given industry sector; comparison of non-nanotechnologies and nanotechnology based products for a given industry sector

- broadly, nanotechnologies can be categorised into several “generations” with increasing complexity such as:
- “passive” nanomaterials: including simple nanoparticles and materials containing them such as coatings and nano-composites, imaging agents, paints, etc.
- “active” nanomaterials: e.g. those that can respond to an energy input or which are designed to interface with biological systems, e.g. some drug delivery systems that release a drug under certain physical or chemical conditions, scaffolds for regenerative medicine, nanoscale electronic systems, etc.
- “self-assembled” or “programmed” nanosystems, e.g. nanomaterials that can form templates for the assembly of other nanomaterials, self-assembling bio-nanosystems, biomimetic nanosystems. There are relatively few commercial examples of these at present but there is research interest, e.g. in materials that could potentially be used in the regeneration of tissues or organ function (bone is an example of a natural self-assembled bio-nanosystem) and biomaterials assembled with the help of DNA templates.

Practical examples; practical examples of the use of Nano-based products in a given industry sector; financial benefits to businesses; environmental benefits

a wide range of possible and easily-obtainable examples available in areas such as;

- cosmetics (sunscreens, liposomal carriers)
- sports goods (carbon nanotubes in tennis and squash racquets and golf club shafts, quantum-tunnelling composites as switches for personal entertainment and communications in skiwear), water-resistant coatings for sports shoes)
- textiles (enhanced-wear, stain- and water-resistant fabrics, nanosilver-treated antibacterial materials)
- household paints
- products for automotive paint and screen treatment
- a variety of possible modes of action depending on material or product. Trainee should investigate these.
- the trainee should investigate the benefits and possible risks in the context of the examples chosen. The following are themes that could be explored and which could be useful in explaining risk and benefit:
- are there free nanomaterials in the product or are they bound into the product and therefore unlikely to come into contact with the body or environment?
- at what stage(s) in the lifecycle of the product are there like to be risks of exposure?
- is there a <u>hazard</u> present (possibility of harm to people or to the environment)?
- what is the likelihood of harm occurring and, if so, how serious are the likely consequences (<u>risk</u>)?
- have efforts been made to reduce the risk?
- how can the benefit be assessed?
- has a balance between risks and benefits been made and, if so, what are the criteria for the acceptability of any risks?
- to be chosen in the context of the sector in which the trainee will be working.

The lists above can be a starting point.

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Delivery

Ideally, this unit would be delivered using a combination of theory, video content, practical demonstrations, hands-on lab experiments, and investigative assignments.

To enable learners to understand the concept of nano-science and nanotechnologies through theory and video content.

To enable learners to understand through practical demonstrations and hand-on lab experiments;

- The different generations of nano-based products and their development over the last 50 years
- Health & Safety aspects related to nano-based products
- Practical benefits and
- Applications

Through investigative assignments, enable learners to understand and identify nano-based products available for their industry sector, the benefits of these products and their application within their industry sector.

Tutors should ensure that learners are aware of any hazards and safe working practices associated with the use of nano-based products during lab sessions.

The learning outcomes are designed to be integrated areas a range of assignments. For employed learners, assignments could be designed to reflect aspects of their work. The use of industrial visits can also be used to enhance learners' knowledge of processes and implementation carried out by companies in their industry sector.

Centres should have access to an appropriate range of specialist equipment and products for lab experiments. Learners will require instruction in the safe handling and storage of products and equipment.

Resources

- Learners need access to library and ICT resources to support the theory part of this unit's delivery.
- Learners need access to Nano-lab kits and demonstrations for hands on practical part of this unit's delivery

Contact for Nano-lab kits: pallavi.malhotra@newham.ac.uk

Employer Engagement and Vocational Context

Learners will benefit from visits to laboratories engaged in investigations or research into Nanotechnological processes, manufacturers of Nano-based products and companies providing Nano-application services