

Questionnaires for summative assessment and validation of prior learning / learning outcomes

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Part 1. Nanotechnology

The correct answer is underlined, the explanation for wrong answers is included. Extra questions that may be used for additional statistics are marked in red

Standard questions

1. What kind of nanotechnology deliverable has been the most valuable part of the nanotech global market, at least until 2017?
 - a. Nanomaterials
 - b. Nanotools
 - c. Nanodevices
 - d. All of the others hold the same value

Correction:

The correct answer is “Nanomaterials”. As of 2017, while nanotools and nanodevices are emerging as new markets, nanomaterials remain the most valuable part.

2. On which technology readiness level (TRL), commercialization begins to be taken into account?
 - a. Experimental proof of concept
 - b. Technology validated in the lab
 - c. Technology validated in the relevant environment
 - d. Technology demonstrated in the relevant environment

Correction:

The correct answer is “Technology validated in the lab”. At the level of experimental proof of concept, commercialization is not yet an issue. Conversely, validation in an industrially relevant environment requires a preliminary plan for exploitation.

3. What does conceptual nanotechnology refer to?
 - a. Use of nanoobjects directly in applications
 - b. Use of nanoobjects as components of devices
 - c. Use of a nanoperspective to understand systems or phenomena
 - d. None of the above

Correction:

The correct answer is “Use of a nanoperspective to understand systems or phenomena”, which is the definition of conceptual nanotechnology.

4. Which type of material displays the largest bandgap?
 - a. metals

- b. metalloids
- c. **non- metals**
- d. heavy metals

Correction:

The correct answer is “non-metals”, which includes semiconductors and insulators. Metals typically display no band gap and metalloids an intermediate profile between those of metals and non-metals.

5. What governs the type and number of bonds that may be created by an atom?
- a. Mass of the atom
 - b. **Valence electrons**
 - c. Molecule architecture
 - d. Number of neutrons in the nucleus

Correction:

The correct answer is “valence electrons”, which are outer-shell electrons that are prone to form chemical bonds. The atomic mass and the number of neutrons exert little effect on the chemical behavior of an atom, whereas the molecule architecture rather follows from the type and number of bonds of an atom.

6. What is electrostatic screening?
- a. Repulsion of the electron clouds of atoms that are brought very close to each other
 - b. **Reduction of the electrostatic interactions between atoms or molecules by the dielectric effect**
 - c. Process of turning of a set of metal atoms into positively charged ions and clouds of free electrons
 - d. Stabilization of a system with the vibrations transferred from a light atom placed between two heavy atoms

Correction:

The correct answer is “Reduction of the electrostatic interactions between atoms or molecules by the dielectric effect”, which is the definition of electrostatic screening.

7. Systems confined into the nanoscale in three dimensions are called...
- a. ... 1D nanomaterials
 - b. ... 2D nanomaterials
 - c. ... 3D nanomaterials
 - d. ... **none of the others**

Correction:

The correct answer is “... none of the others”, because systems confined to the nanoscale in all three spatial dimensions are rather 0D nanomaterials. Typical examples of 0D nanomaterials are quantum dots, while 1D or 2D nanomaterials respectively include quantum wires or quantum wells, whose charge carriers are confined in two or one dimensions.

8. What is the difference between bottom-up and top-down approaches in nanomaterial processing and fabrication?
- Bottom-up is invented by humans, while top-down is rather inspired by nature
 - Bottom-up methods are based on highly-controlled chemical decomposition while top-down methods are based on highly-controlled physical agglomeration
 - In top-down approaches, nanostructures are produced by sequential patterning of layers, while, in bottom-up approaches, nanostructures are produced through controlled deposition or growth**
 - Bottom-up is more popular in Oceania and South America, while top-down is more popular in Asia, Europe and North America

Correction:

The correct answer is “In top-down approaches, nanostructures are produced by sequential patterning of layers, while, in bottom-up approaches, nanostructures are produced through controlled deposition or growth”, which is a proper definition of both approaches.

9. What is the driving force behind self-assembly?
- Minimization of free energy**
 - Size of the building blocks
 - Size of the aggregates that are formed
 - Covalent interactions

Correction:

The correct answer is “Minimization of free energy”. Therefore, all underlying chemical and physical processes need careful understanding, in order to gain control and exploit the full power of self-assembly.

10. What is steric stabilization in the colloidal methods for nanoparticle synthesis?
- Stabilization of particles by using concentration gradients
 - Stabilization of particles by varying pH through their isoelectric point
 - Stabilization of particles by using nonionic macromolecules as capping agents**
 - Stabilization of particles by using magnetic fields

Correction:

The correct answer is “Stabilization of particles by using nonionic macromolecules as capping agents”, which is the definition of steric stabilization. Instead electrostatic stabilization is based on the mutual repulsion of like charges and may involve pH or salinity.

11. What is photolithography, one of the nanofabrication methods?
- Direct writing of patterns in a photoresist by using an electron or an ion beam
 - Formation of hierarchical structures, as a result of self-assembly
 - Exposing of a photoresist to light through a mask, which may be etched in a next stage**
 - Using of a highly focused laser beam to write topographical patterns in a substrate or to trap dielectric particles

Correction:

The correct answer is “Exposing of a photoresist to light through a mask, which may be etched in a next stage”, which captures the essential steps of photolithography, as is used to fabricate e.g. integrated circuits in CMOS wafers.

12. In which of the techniques mentioned below a gas undergoes chemical reactions?

- a. Sputtering
- b. Pulsed laser deposition
- c. **Chemical vapor deposition**
- d. Ion beam assisted evaporation

Correction:

The correct answer is “Chemical vapor deposition”, where volatile precursors react or decompose on a substrate to create a deposit. The other methods do not typically imply chemical reactions in a gas phase.

13. When does the concept of negative photoresist apply in photolithography?

- a. Exposed parts contain so-called photoactive components (PACs)
- b. Unexposed parts contain so-called photoactive components (PACs)
- c. **Exposed parts become crosslinked**
- d. Unexposed parts become crosslinked

Correction:

The correct answer is “Exposed parts become crosslinked”. Upon cross-linking, these parts become more inert against a developer solution.

14. How does an atomic force microscope work?

- a. A topography image is created by scanning a conducting tip across a surface, where the tip-surface distance is kept constant by measuring the electric current
- b. An electron beam is scanned across the surface and the backscattered electrons are measured to reconstruct the topography of the surface with nanometer-scale resolution
- c. **A nanometer-sized tip mounted on the end of a flexible cantilever is used to scan a surface. By keeping the deflection of the cantilever constant, a topography image is obtained**
- d. A sharp tip is scanned across a surface, which enhances the lateral resolution of an optical microscope. Features down to a few atoms can be resolved

Correction:

The correct answer is “A nanometer-sized tip mounted on the end of a flexible cantilever is used to scan a surface. By keeping the deflection of the cantilever constant, a topography image is obtained”, which summarizes the basic principles of atomic force microscopy. The other descriptions refer to complementary methods, such as scanning tunneling microscopy or scanning electron microscopy.

15. Diffraction limit means that...:

- a. ... particles that diffract more light appear to be brighter on optical microscopy
- b. ... particles that diffract less light appear to be brighter on optical microscopy
- c. ... particles larger than about the wavelength at play cannot be resolved on optical microscopy
- d. **... particles smaller than about the wavelength at play cannot be resolved on optical microscopy**

Correction:

The correct answer is "... particles smaller than about the wavelength at play cannot be resolved on optical microscopy". According to Abbe, the diffraction limit actually corresponds to the wavelength at play divided by twice the numerical aperture, which may even exceed a factor of three or so. Therefore, a standard optical microscope may be used to resolve most bacteria but not viruses, for instance.

16. How does atomic force microscopy (AFM) work in comparison with electron microscopy (EM)?

- a. With respect to EM, AFM can achieve much higher resolution and is also much faster in acquiring images
- b. **Both techniques achieve comparable resolution in topography, but AFM is able to access more parameters of a sample**
- c. With respect to EM, AFM is much older and therefore more established over the years
- d. To some extent, AFM can provide chemical information, which is impossible with EM

Correction:

The correct answer is "Both techniques achieve comparable resolution in topography, but AFM is able to access more parameters of a sample". In turn, AFM is typically slower than EM in acquiring images. EM is much older than AFM. Both methods hold the potential to provide chemical information, e.g. by the use of electron energy loss spectroscopy or energy-dispersive X-ray spectroscopy in combination with EM.

17. What distinguishes environmental scanning electron microscopy?

- a. **Degraded vacuum in SEM chamber**
- b. Degraded vacuum in electron gun region
- c. Improved image resolution
- d. More eco-friendly implementation of SEM

Correction:

The correct answer is "Degraded vacuum in SEM chamber", which is a convenient solution to image samples that are wet, uncoated or exposed to an atmosphere, often at the expense of lower image resolution.

18. Active targeting is one of the methods used in nanomedicine. What does it mean?

- a. Nanoparticles are directly injected into the site of the body that is affected by the disease
- b. Nanoparticles smaller than about 200 nm enter the tumor or inflammatory site through its leaky vasculature
- c. Nanoparticles are introduced into the body and then imaged after reaching the tumor or inflammatory site
- d. **Nanoparticles are decorated with specific ligands that are able to bind and/or undergo uptake into a certain population of cells**

Correction:

The correct answer is “Nanoparticles are decorated with specific ligands that are able to bind and/or undergo uptake into a certain population of cells”. When the biological target is a tumor or inflammatory site, active targeting may add to passive targeting, whereby nanoparticles smaller than about 200 nm permeate its leaky vasculature.

19. Where do nanoparticles mostly accumulate?

- a. Brain
- b. **Liver**
- c. Lymphatic system
- d. Kidneys

Correction:

The correct answer is “Liver”. Upon systemic injection, most nanoparticles accumulate in the reticuloendothelial system in the liver and the spleen.

20. What is meant by lab-on-a-chip?

- a. Laboratory facility that deals with the production of microfluidic chips
- b. **Microfluidic device that integrates one or several laboratory functions within a single chip**
- c. Array of silicon chips used in an analytical lab to perform multiple assays
- d. Laboratory facility that is based on an integrated circuit

Correction:

The correct answer is “Microfluidic device that integrates one or several laboratory functions within a single chip”, which is a general definition for lab-on-a-chip.

21. Which of the following organelles is responsible for the production of energy?

- a. Golgi apparatus
- b. Ribosomes
- c. **Mitochondria**
- d. Nuclei

Correction:

The correct answer is “Mitochondria”, which are mostly responsible for the production of adenosine triphosphate (ATP). The principal functions of ribosomes and Golgi apparatus are to synthesize and dispatch proteins, respectively.

22. What is the photoelectric effect?

- a. **Emission of electrons from an irradiated material**
- b. Emission of light upon applying voltage to a material
- c. Emission of light upon applying an electric current to a material
- d. Emission of electrons from a material that produces light

Correction:

The correct answer is “Emission of electrons from an irradiated material”, which is a basic definition for the photoelectric effect.

23. What does doping of materials mean?

- a. Process of production of ultrapure semiconductors
- b. In most cases, intentional introduction of semiconductor atoms into a metal alloy
- c. **In most cases, intentional introduction of different elements into a semiconductor**
- d. Process used to pattern a CMOS device

Correction:

The correct answer is “In most cases, intentional introduction of different elements into a semiconductor”, with the intent to create charge carriers. For instance, the introduction of pentavalent atoms, such as antimony, arsenic or phosphorus, in silicon generates free electrons, whereas that of trivalent atoms, such as boron, gallium or indium, free holes.

24. Why have organic solar cells received so much attention?

- a. Because of their high efficiency
- b. Because of their high diffusion length
- c. **Because of their compatibility with flexible electronics**
- d. Because of their potential to produce ultrapure hydrogen

Correction:

The correct answer is “Because of their compatibility with flexible electronics”, although their stability, efficiency and diffusion length (below about 10 nm in most organic semiconductors) remain problematic.

25. Which of the statements below is true?

- a. **Efficient fuel oxidation and oxygen reduction in fuel cells is made possible by effective catalysts**
- b. Pt is a perfect catalyst for fuel cells and ongoing research focuses on Pt-based technology
- c. Most fuels in fuel cells undergo reduction to directly convert chemical energy into electrical energy
- d. All of the others

Correction:

The correct answer is “Efficient fuel oxidation and oxygen reduction in fuel cells is made possible by effective catalysts”. Current research focuses on the replacement of Pt-based catalysts with

innovative materials that may combine better availability, stability and selectivity for the production of valuable chemicals.

26. Which of the methods below is the most promising for hydrogen storage?

- a. Hydrogen compression
- b. Hydrogen liquefaction
- c. **Use of materials that reversibly release hydrogen upon heating**
- d. Use of materials that reversibly release hydrogen upon storage

Correction:

The correct answer is “Use of materials that reversibly release hydrogen upon heating”. Hydrogen compression or liquefaction are possible but energy consuming and inefficient in terms of energy per volume.

27. What is a plasmon?

- a. Natural mineraloid shimmering due to light diffraction from its nanostructure
- b. Device that converts light into heat and vice-versa
- c. **Collective oscillation of free electrons in a metal**
- d. None of the others

Correction:

The correct answer is “Collective oscillation of free electrons in a metal”, which may be driven by light.

28. Why can single-electron transistors be called artificial atoms?

- a. Because of their small size
- b. Because of their abundance of protons, electrons and neutrons
- c. **Because of their discrete spectra**
- d. Because single-electron transistors are coupled via tunnel barriers to source and drain reservoirs

Correction:

The correct answer is “Because of their discrete spectra”. All other options are either not distinctive or fail to seize the atom-like features of single-electron transistors.

29. What is a typical feature of a photonic crystal?

- a. A photonic crystal is a periodic nanostructure
- b. A photonic crystal may display one or more photonic band gaps
- c. A photonic crystal is able to modulate light
- d. **All of the others**

Correction:

The correct answer is “All of the others”.

30. Which of the following statements is false?

- a. Plasmonic waveguides provide tight confinement. However, a metal being in contact with an electric field, energy losses may be very high
- b. Light in a waveguide travels as a combination of modes, which are the solution of the wave equation and a boundary condition for the waveguide
- c. **If the angle of incidence of light in a slab waveguide is larger than 0, than total internal reflection occurs**
- d. Silica on silicon technology for the production of waveguides enjoys very small energy losses, but the length of the devices (cm range) is hardly suitable for long scale integration

Correction:

The correct answer is “If the angle of incidence of light in a slab waveguide is larger than 0, than total internal reflection occurs”, which is wrong. The condition for total internal reflection in a slab waveguide is that the angle of incidence is smaller than the arcsine of the ratio of the indexes of refraction of the outer to the inner dielectrics.

31. What is the correct definition for photoelectric effect?

- a) The photoelectric effect refers to the emission of photons when an electric field is applied to a material
- b) **The photoelectric effect refers to the emission of electrons when light shines upon a material, such as a metal**
- c) The photoelectric effect inhibits the emission of electrons when light strikes upon a metal
- d) The photoelectric effect refers to the heating of a metal upon optical excitation

Correction:

The correct answer is “The photoelectric effect refers to the emission of electrons when light shines upon a material, such as a metal”, which is a general definition of this phenomenon.

32. Which is the earliest photovoltaic technology?

- a) Dye sensitised solar cells
- b) Organic solar cells
- c) **Silicon-based solar cells**
- d) Thin film solar cells

Correction:

The correct answer is “Silicon-based solar cells”, which were first demonstrated at Bell Laboratories in 1954 and are now available on the market for a broad variety of applications. Thin film solar cells have commercially been exploited since the late 1970s and are now available for such contexts as building-integrated installations and vehicle charging systems. Dye-sensitized solar cells and organic solar cells have mostly been developed since the late 1980s and still represent a niche market, as of 2017.

33. What is a fuel cell?

- a) **A device that directly converts the chemical energy of a fuel into electrical energy**
- b) A device that converts electrical energy from a fuel into thermal energy
- c) A device that makes use of a fuel to store chemical energy

d) A device to store electrical energy in a fuel

Correction:

The correct answer is “A device that directly converts the chemical energy of a fuel into electrical energy”, which is a general definition for a fuel cell.

34. How does the theoretical efficiency of a fuel cell compares to that of a thermal machine?

- a) Both efficiencies approach unity at room temperature
- b) At variance with that of a thermal machine, the theoretical efficiency of a fuel cell does not depend on temperature
- c) The theoretical efficiency of a fuel cell $\Delta G_f / \Delta H_f$ is typically much lower than that of a thermal machine $1 - T_1 / T_2$
- d) **None of the others is true**

Correction:

The correct answer is “None of the others is true”, because the theoretical efficiency of a fuel cell is $\Delta G_f / \Delta H_f$, which is typically much higher than that of a thermal machine $1 - T_1 / T_2$ and depends on temperature through the thermodynamic potentials.

35. Why is there ongoing research to replace platinum with more innovative catalysts in fuel cells?

- a) Platinum is too rare to satisfy the potential demand for fuel cells
- b) Platinum-based anodes suffer from poisoning even at open-circuit
- c) Innovative catalysts at the anode may be engineered to combine the production of energy and valuable chemicals
- d) **All options are true**

Correction:

The correct answer is “All options are true”.

36. What is the typical output voltage of a fuel cell?

- a) **Fractions of a Volt and depends on current density**
- b) 220 – 240 V in Europe
- c) Around a kV, when fed with ethanol
- d) Around a kV, when platinum is substituted with iron as a catalyst

Correction:

The correct answer is “Fractions of a Volt and depends on current density”, which is on the order of the standard electrode potentials of most redox reactions of interest and decreases with current density through the effect of polarization.

37. What variable plays the principal role in the spectrum of quantum dots?

- a) Dimensionality
- b) **Size**
- c) Pressure and temperature
- d) Refractive index of surrounding medium

Correction:

The correct answer is “Size”. Pressure, temperature or the refractive index of the surrounding medium may play a secondary role, in the context of quantum dots. Their dimensionality is 0D by definition.

38. What nanomedicine product has already become a clinical option?

- a) **Liposomes, which may be used to enhance the delivery of cytotoxics to tumors**
- b) Quantum dots, which have extensively been used for oral administration since 1988
- c) Penicillin, which is emerging as an innovative solution to kill superbugs
- d) Plasmonic nanoparticles, such as CdSe quantum dots

Correction:

The correct answer is “Liposomes, which may be used to enhance the delivery of cytotoxics to tumors”. As of 2017, the biomedical use of quantum dots, such as CdSe nanoparticles or their variants, is still hampered by regulatory constraints. Penicillin is not nanotech nor quite useful against superbugs and CdSe quantum dots are not plasmonic per se.

Case study-like questions

Case 1: CSEM is a private, non-profit Swiss research and technology organization that manufactures organic photovoltaic (OPV) cells through a high throughput process. Which of the following statements may apply?

- 1) **CSEM uses spin-coating as a flexible approach to gain control over the thickness of the various organic layers of their OPV cells**
- 2) CSEM uses a nitrogen atmosphere, in order to dope the p side of the heterojunction of their OPV cells
- 3) CSEM uses Pt nanoparticles as catalysts to enhance the production of hydrogen from their OPV cells
- 4) The lack of flexibility represents the major bottleneck for the commercialization of OPV cells

Correction:

The correct answer is “CSEM uses spin-coating as a flexible approach to gain control over the thickness of the various organic layers of their OPV cells”. A nitrogen atmosphere is actually used to prevent oxidation of the various organic layers and Pt nanoparticles are used to print electrical contacts. Flexibility is one of the key advantages of OPV cells.

Case 2: Cella Energy is a British company that was co-founded by Prof Stephen Bennington in 2011 as a spin-out from UK Government’s Science and Technology Facilities Council. Ever since its foundation, Cella Energy has developed novel hydrogen storage materials that are capable to release large quantities of hydrogen when heated to relatively low temperatures. These materials make it possible and safe to store and transport hydrogen at room temperature and pressure. With the intent to enhance the release of

hydrogen from composites of ammonia borane and polyethylene oxide, what manufacturing technique may Prof Stephen Bennington and coworkers have introduced?

- 1) **Electrospinning as a versatile tool to obtain large specific surface area**
- 2) Pelletizing as a convenient solution for transportation
- 3) Sintering at temperatures above 400°C in order to enhance the electrical conductivity of the composites
- 4) All of the others are plausible

Correction:

The correct answer is “Electrospinning as a versatile tool to obtain large specific surface area”. Pelletizing is indeed used as a convenient solution to transport and dispense the fuel, but this step is not relevant and potentially even counterproductive to enhance the release of hydrogen. Sintering at temperatures above 400°C is rather incompatible with ammonia borane under standard conditions.

Case 3: Colorobbia is an Italian company that manufactures colours for ceramics and performs research on new materials for a broad variety of applications, including hybrid solutions for medical diagnostics and treatments. In 2015, Colorobbia submitted a patent application on a new technology to couple magnetite nanoparticles to tumor tropic T-cells in vitro. These cells may be harvested from a patient and then re-injected back into her / his bloodstream after amplification and modification with magnetite nanoparticles. This combination was designed to...

- a) ... cut costs for the preparation of magnetite particles, at the expense of their colloidal stability in a biological fluid
- b) ... overcome the principal biological barriers, such as the reticuloendothelial system, and deliver a magnetic contrast agent to a tumor**
- c) ... reach the ideal hydrodynamic size to exploit the enhanced permeability of tumor blood vessels and deliver a magnetic contrast agent to a tumor
- d) ... cut costs for the preparation of magnetite particles, at the expense of their potential to reach a tumor

Correction:

The correct answer is “... overcome the principal biological barriers, such as the reticuloendothelial system, and deliver a magnetic contrast agent to a tumor”. The use of tumor-tropic cells for the delivery of nanoparticles to tumors is an alternative that exploits the innate tropism of these vehicles to cross the biological barriers and reach the tumor microenvironment. Tumor-tropic cells are much too large to match the anomalous porosity of tumor blood vessels and so leave the bloodstream through more complex mechanisms, such as diapedesis. While this approach lowers most requirements of e.g. colloidal stability, stealth profile or specificity, its costs are likely to suffer from the need for tumor-tropic cells as well as a high consumption of nanoparticles.

Case 4: In 2007, Toshiba claimed the validation of an innovative technology to pattern semiconductors with a lateral resolution of ~ 22 nm. What technology could it be?

- a) Organic light emitting diodes
- b) Nanoimprint lithography**
- c) Moore's law
- d) 436-nm photolithography

Correction:

The correct answer is "Nanoimprint lithography". 436-nm photolithography is insufficient to reach a lateral resolution of 22 nm per se, because of the diffraction limit. The other options are not pertinent.

Part 2. Innovation management

The correct answer is underlined, the explanation for wrong answers is included. Extra questions that may be used for additional statistics are marked in red

Standard questions

1. Which of the research topics stated below cannot be regarded as basic research topic?

- a) Investigation of the Earth gravity field
- b) Construction of the laser scalpel prototype
- c) Genotyping of human rotavirus VP4
- d) All of the others can be regarded as basic research topics

CORRECTION: The right answer is “construction of the laser scalpel prototype”. Basic research cannot be linked to the stage of prototype construction. The other options are at a level of generalisation that is enough to be considered as basic research.

2. Creativity and innovation:

- a) Both terms have the same meaning
- b) Innovation is an element of creativity
- c) Creativity is an element of innovation
- d) Innovation has little to do with creativity

CORRECTION: The right answer is “creativity is an element of innovation”. Innovation is a broader concept than creativity.

3. The first stage of the so-called *technology push* model of innovation is:

- a) Basic research
- b) Market research
- c) Market introduction
- d) Production

CORRECTION: The right answer is “basic research”. Market research relates to the stage of “market need” in the so called “market pull” model, while “market introduction” and “production” are later stages of the “technology push” model.

4. Which of the elements below is out of place in the context of Schumpeter's definition of innovation:
- The introduction of a new quality of good
 - The introduction of a new method of production
 - The preparation of the design of new product
 - The re-organization of an industry

CORRECTION: The right answer is "The preparation of the design of new product". Innovation encompasses more elements than product design alone. The other options belong to the innovation types that were identified by Schumpeter.

5. Which of the statements below relates to the Chain-Linked Model of Innovation:
- Innovative process must start from market research
 - Innovative process can proceed in different directions
 - Innovative process is linear
 - None of the others

CORRECTION: The right answer is "Innovative process can proceed in different directions". According to the Chain-Linked Model of Innovation, an innovative process can start at any stage identified by the model.

6. Incremental innovation means:
- Small improvements that occur e.g. in the company production process
 - A good or service that is new or substantially improved
 - A new market that is opened
 - None of the others

CORRECTION: The right answer is "small improvements that occur e.g. in the company production process". Incremental innovation is not related with substantial improvement nor with new markets.

7. What indicator is used by EUROSTAT to distinguish high-tech sectors?
- Number of innovations to sales
 - Research and development expenditures to sales
 - Market research expenditures to sales
 - All of the others

CORRECTION: The right answer is "Research and development expenditures to sales". Number of innovations is a poor indicator in statistics due to measurement errors and market research expenditures does not directly relate to new technologies.

8. "Narrow view" of commercialization means:
- The last stage of the innovation process
 - Limited access to resources in the commercialization process
 - Research to market process
 - Limited knowledge of how to commercialize

CORRECTION: The right answer is “The last stage of the innovation process”. Commercialization may be understood as the process from mind to market, or the last stage of the innovation process. The last one is called “narrow view” and relates to commercialization definition rather than resources or knowledge of how to commercialize. The research to market process describes the wide view of commercialization.

9. Most probably, a lack of adequate resources for commercialization may be the reason for failure of...

- a) ... the licensing strategy
- b) ... the independent commercialization strategy
- c) ... the commercializing with partners strategy
- d) ... the patent selling strategy

CORRECTION: The right answer is “... the independent commercialization strategy”. If the company wants to commercialize a technology and lacks any of the required resources, it will fail, e.g. not enough knowledge to create a prototype, no capital, no distribution channels, no production facilities to manufacture the product, etc.. All other options may be useful strategies for companies that lack adequate resources to commercialize by themselves.

10. In order to make a decision whether to commercialize a technology or not, one must have...

- a) ... an assessment report of the commercial potential
- b) ... a business plan
- c) ... the agreement with venture capital
- d) ... detailed financial calculations

CORRECTION: The right answer is “... an assessment report of the commercial potential”. In order to commercialize an innovation, one must know its commercial value, potential customers, barriers that may appear in the commercialization process, and intellectual property status. In order to reduce commercialization risks, the commercial potential must be assessed. The document allowing one to make the decision whether to commercialize or not is called an assessment report of commercialization potential. A business plan is needed in the development stage to make a decision about the strategy for commercialization. Not every company uses venture capitalists as financial partners. Also detailed financial information is needed in the development stage to calculate risks and check commercialization profitability. To make a decision to commercialize, one needs to know whether there exists a market for the innovation or not, so first one needs to assess the commercial potential of the innovation.

11. The business model for a (nano) technology commercialization venture is necessary when...

- a) ... the company or research team are making the decision about moving from the idea stage to the development stage
- b) ... the company or research team are making the decision about moving from the research stage to the development stage
- c) ... the company or research team are making the decision about moving from the development stage to the diffusion stage
- d) ... the company or research team are making the decision about moving from the critical factor analysis stage to the research stage

CORRECTION: The right answer is “... the company or research team are making the decision about moving from the development stage to the diffusion stage” and so need to choose the strategic model for market implementation and decide how to enter the market, e.g. alone or with venture capital. Business models

are usually created in the development stage, together with business plans. There is no critical factor analysis stage, because different factors influencing the commercialization process are analysed at different stages.

12. “Bridges” and “mobilizing resources” are typical terms used to describe the commercialization model by...

- a) ... Goldsmith
- b) ... Product Development Institute
- c) ... De Getter
- d) ... V.K. Jolly

CORRECTION: The right answer is “V.K. Jolly”. These terms are used only in this model.

13. What may be useful resource providers in the idea stage in the (nano) technology commercialization process?

- a) Universities and R&D institutes
- b) Suppliers of components to manufacture the product
- c) Export agencies
- d) Promotion institutions

CORRECTION: The right answer is “Universities and R&D institutes”, who hold knowledge that may be needed at this stage. The other entities may be needed at the development stage or later.

14. What is one of the most desirable competencies in the commercialization management process?

- a) Punctuality
- b) Readiness to take risk
- c) Strategic thinking and team-building
- d) Negotiation skills

CORRECTION: The right answer is “Strategic thinking and team-building”. Commercialization is a process that needs strategic thinking, creating a business model, and predicting a risk that may be difficult to assess. All this calls for different people with different skills, so team-building is necessary to meet the objectives of the commercialization process. Punctuality and readiness to take risk are not competencies. Negotiation skills is important but not the most decisive competence for commercialization success. If the commercialization team does not have a good strategy, the process may not be successful.

15. What is the key success factor in the “Define the stakeholders and required support” phase of the economic assessment process?

- a) To develop a rationale for the support required from the stakeholders
- b) To identify the intellectual property (IP) state of the (nano) technology
- c) To contact end users and potential licensees
- d) None of the others

CORRECTION: The right answer is “To develop a rationale for the support required from the stakeholders”. Identifying the intellectual property state of the (nano) technology or contacting end users and potential licensees are covered in other phases of the economic assessment process.

16. What is the key success factor in the “Identify barriers and opportunities” phase of the economic assessment process?
- To identify the required human / technological / other resources during the commercialisation phase
 - To outline potential ways to overcome the barriers
 - To contact end users and potential licensees
 - None of the others

CORRECTION: The right answer is “To outline potential ways to overcome the barriers”. Identifying the required human / technological / other resources during the commercialisation phase or contacting end users and potential licensees are covered in other phases of the economic assessment process.

17. What technology readiness level (TRL) corresponds to the definition “Actual system completed and qualified through test and demonstration”?
- 7
 - 8
 - 9
 - 5

CORRECTION: The right answer is “8”. TRL 5, 7 and 8 have different definitions.

18. What is one of the key questions to address in the “Potential Commercial Markets / Applications” section of the “Economic value assessment methodology”?
- What products / processes could result from the invention / research results implementation?
 - Who are the potential stakeholders / customers / end users?
 - What feedback is given by potential buyers or end users?
 - None of the others

CORRECTION: The right answer is “What products / processes could result from the invention / research results implementation?”. The other questions are asked in different sections of the “Economic value assessment methodology”.

19. What is one of the key questions to address in the “Market Interest” section of the “Economic value assessment methodology”?
- What products / processes could result from the invention / research results implementation?
 - Who are the potential stakeholders / customers / end users?
 - What feedback is given by potential buyers or end users?
 - None of the others.

CORRECTION: The right answer is “What feedback is given by potential buyers or end users?”. The other questions are asked in different sections of the “Economic value assessment methodology”.

20. What is one of the key competences of a commercialisation / (nano) technology transfer manager in the “Communication” area?
- Ability to creatively modify tools and procedures for the implementation of tasks
 - Ability to ask questions in the context of obtaining information

- c) Ability to take responsibility for the effect of the team
- d) Ability to apply tools of risk analysis in the commercialisation process

CORRECTION: The right answer is “Ability to ask questions in the context of obtaining information”. The other abilities are key competences in different areas.

21. What is one of the key competences of a commercialisation / (nano) technology transfer manager in the “Business awareness” area?

- a) Ability to identify potential opportunities and barriers to the development and implementation of innovation
- b) Ability to select tools of organizational communication (channels and forms of organizational communication) for the required context
- c) Ability to recognize the essential characteristics of the market, industry or sector
- d) Ability to engage and support others in teamwork

CORRECTION: The right answer is “Ability to recognize the essential characteristics of the market, industry or sector”. The other abilities are key competences in different areas.

22. What are core marketing concepts focused on?

- a) Advertising
- b) The customer’s needs
- c) Selling techniques
- d) Persuading customers

CORRECTION: The right answer is “The customer’s needs”, because the customer is a starting point for every marketing activity. Advertising is one of the many tools for promotion. Selling techniques are focused on understanding customers and markets. Persuading customers are based on satisfying customer’s needs.

23. Collecting data from primary sources is...

- a) ... faster and cheaper than secondary research
- b) ... very important in the process of changing innovative ideas into products
- c) ... useless in new product development
- d) ... a process of communicating value proposition

CORRECTION: The right answer is “... very important in the process of changing innovative ideas into products”, since there is not much secondary data about new markets.

24. What does PEST analysis refer to?

- a) The internal environment of a company
- b) The micro environment of a company
- c) The macro environment of a company
- d) The company’s portfolio of products

CORRECTION: The right answer is “The macro environment of a company”. Political, economic, social and technological (PEST) analysis refers to elements of the environment that a company cannot control. The other options refer to different analyses.

25. Brand is a part of...

- a) ... the core product
- b) ... the actual product
- c) ... the augmented product
- d) ... non-label product

CORRECTION: The right answer is "... the actual product". The actual product includes quality, features and design, brand name, packaging and other attributes that combine to deliver core product benefits.

26. What are relative market share and market growth controlling aspects for?

- a) Brand awareness analysis
- b) The marketing mix
- c) The BCG matrix
- d) General Electric matrix

CORRECTION: The right answer is "The BCG matrix". Relative market share and market growth help to determine the position of a product or other strategic business unit on a BCG matrix.

27. Products that are in high growth markets with a relatively high share of that market on the BCG matrix are called...

- a) ... stars
- b) ... question marks
- c) ... cash cows
- d) ... dogs

CORRECTION: The right answer is "... stars".

28. Business-to-Business marketing involves the exchange of goods and services that businesses purchase for purposes other than general consumption. What is this process mainly driven by?

- a) A simple, single-step buying process
- b) More emotional buying decisions
- c) Trust-based relationships
- d) Less complex decisions

CORRECTION: The right answer is "Trust-based relationships". Building trust and relationships is very important on B2B markets, as the company knows its partners better and establishes longer-time collaborations.

29. When can one patent her / his invention?

- a) Just after she / he showed it during a fair
- b) As soon as it is ready for commercialization
- c) After she / he published it on a university forum
- d) None of the others

CORRECTION: The right answer is "As soon as it is ready for commercialization". The invention must not be published prior to filing a patent application.

30. When would it be better to go into a trade secret rather than a patent?

- a) When the invention is easy to get around but difficult to reverse-engineering
- b) When it is not possible to get around the invention
- c) When you have no money
- d) When it has already been published

CORRECTION: The right answer is “When the invention is easy to get around but difficult to reverse-engineering”, so that competitors cannot legally copy the method or product.

31. What is the territorial range of a patent?

- a) Continental range
- b) All EU countries if the patent is filed in one of the EU countries
- c) An individual country
- d) It depends on the type of patent procedure, e.g. national / PCT / EPC, etc.

CORRECTION: The right answer is “It depends on the type of patent procedure, e.g. national / PCT / EPC, etc.”, as is chosen by the applicant.

32. What is the incentive related to the licence being granted?

- a) Lesser costs for patenting
- b) Making sure nobody else will make the product / service
- c) Royalty
- d) Lesser costs for marketing

CORRECTION: The right answer is “Royalty”. The other options do not relate to licensing and its incentive.

33. What is the right type of a licence?

- a) Non-exclusive licence
- b) Self-appointed licence
- c) Future licence
- d) Former licence

CORRECTION: The right answer is “Non-exclusive licence”, whereby the same rights may be granted to several licensees within the same scope or context.

34. When should a license not be granted?

- a) The partner agrees to all conditions
- b) The IP of the licence is weak
- c) The country of the licensee is very far away
- d) None of the others

CORRECTION: The right answer is “The IP of the licence is weak”. The other options should not discourage from licensing.

35. What is an NDA?

- a) The ability to identify potential opportunities and barriers to the development and implementation of an innovation

- b) An agreement between at least two parties leading to joint ownership of a patent
- c) A legal contract between at least two parties that outlines confidential material, knowledge, or information that the parties wish to share
- d) None of the others

CORRECTION: The right answer is “A legal contract between at least two parties that outlines confidential material, knowledge, or information that the parties wish to share”. The meaning of NDA is non-disclosure agreement and aims to restrict access to certain material, knowledge, or information by third parties.

36. What is a trade secret?

- a) Confidential business information giving an enterprise a competitive edge
- b) A secret way of selling and buying products and services
- c) Confidential way of producing goods
- d) All of the others

CORRECTION: The right answer is “Confidential business information giving an enterprise a competitive edge”, which is a general definition for trade secret.

37. What is there in the Innovation Centre model of creativity?

- a) 4 distinct phases: probotyping, provotyping, prototyping, and presentyping
- b) Several methods of creativity that are selected from a tool box of innovation
- c) Processes of human resources management focused on boosting creativity
- d) None of the others

CORRECTION: The right answer is: “4 distinct phases: probotyping, provotyping, prototyping, and presentyping”. The Innovation Centre model of creativity consists of 4 linked stages and is more than boosting creativity.

38. Key circumstances for boosting creativity include...

- a) ... imposing high pressure on employees to force their motivation
- b) ... personal motivation and the ability to take risk
- c) ... high task specialisation
- d) ... narrow and specialized knowledge

CORRECTION: The right answer is “... personal motivation and the ability to take risk”. High pressure is usually a bad way to motivate people and is a possible creativity killer. A real creative approach relates to a broad perspective and interdisciplinary work

39. Wishful Thinking is a technique where...

- a) ... first of all, resources are found and then creative processes can be unlimited
- b) ... it is emphasised that everything is possible and that fantasy should be used
- c) ... only people with enormous creative potential can be involved
- d) None of the others.

CORRECTION: The right answer is “... it is emphasised that everything is possible and that fantasy should be used”. Wishful Thinking is a technique that is accessible to everybody.

40. Why is recognising stakeholders so crucial in the technology development process?

- a) Stakeholders are obstacles throughout the process
- b) Stakeholders are the only source of funding
- c) Stakeholders can be allies throughout the whole process, or for part of it
- d) None of the others

CORRECTION: The right answer is “Stakeholders can be allies throughout the whole process, or for part of it”. The other options are a poor or mistaken definition of stakeholders.

41. In the process of preparing technology and product development scenarios, several general characteristics of the relevant industry should be included, such as...

- a) ... the possibility of expansion in production and sales
- b) ... potential changes in law
- c) ... identification of organisations involved in technology development financing
- d) None of the others

CORRECTION: The right answer is “... the possibility of expansion in production and sales”. The other options are not features of the relevant industry that may affect technology and product development scenarios.

42. What does a Business Model Canvas consist of, according to A. Osterwalder and Y. Pigneur?

- a) Several independent elements, including key activities, key resources, value propositions, customer segments, etc
- b) Several dependent elements in two main streams
- c) Two basic streams, i.e. cost structure and revenue streams
- d) None of the others

CORRECTION: The right answer is “Several dependent elements in two main streams.” Cost structure and revenue streams belong to the same area in this model. The process of creating and delivering value to customers is the other area.

43. The process of implementing R&D results can be presented as a chain of several components:

- a) Initiation, research, transfer, transformation, diffusion
- b) Determination, description, motivation, creation, transfer
- c) Entering, incubation, research, implementation
- d) All of the others

CORRECTION: The right answer is “Initiation, research, transfer, transformation, diffusion”, which are the principal components in the process of implementing R&D results

44. Useful rules of communication in presenting commercialization plans include:

- a) The ability to write complex scientific texts in order to be more convincing
- b) The ability to use easy-to-understand labels and descriptions on charts and graphs
- c) The ability to read a presentation clearly and loudly
- d) An effort to maximise the number of slides

CORRECTION: The right answer is “The ability to use easy-to-understand labels and descriptions on charts and graphs”. Presentations should be clear and simple. Moreover, an effective presentation should not be directly read off the slides like a book.

45. What is venture capital financing?

- a) Debt
- b) Equity
- c) Mezzanine
- d) None of the others

CORRECTION: The right answer is “Equity”. Venture capital is primarily related to capital investment rather than issuing debt

46. Which is a key formal tool used to attract a venture capital investor?

- a) A business plan
- b) A loan application form
- c) A creditworthiness certificate
- d) None of the others

CORRECTION: The right answer is “A business plan”. A loan application form and a creditworthiness certificate may be used for bank procedures.

47. Which is one of the qualitative factors of a company’s creditworthiness analysis carried out by a bank?

- a) Rigour of cost control in a company
- b) Technological input in a company’s products
- c) Age structure of a company’s employees
- d) All of the others

CORRECTION: The right answer is “Rigour of cost control in a company”. The analysis of the technological input in a company’s products is too detailed and expensive to be implemented in a creditworthiness evaluation procedure. The age structure of the company’s employees does not relate to creditworthiness, in most cases.

48. An evaluation of collaterals offered by a company is a part of the procedure done by...

- a) ... a bank
- b) ... a venture capital fund
- c) ... a Business Angel investor
- d) All of the others

CORRECTION: The right answer is “... a bank”. The use of collaterals does not relate to capital investment.

49. Capital markets are not suitable for start-up companies as source of capital. Why?

- a) Start-up companies require too small an amount of external capital
- b) Start-up companies are not able to provide collaterals
- c) Start-up companies are not able to pay interests related to capital investment
- d) All of the others

CORRECTION: The right answer is “Start-up companies require too small an amount of external capital”. Collaterals and interests do not relate to capital investment.

50. What does Due Diligence relate to?

- a) Distribution of shares in the company
- b) Checking the technical, economic and legal conditions for the implementation of the innovative project
- c) Support received from a venture capital investor
- d) Presentation of the business idea.

CORRECTION: The right answer is “Checking the technical, economic and legal conditions for the implementation of the innovative project”. The other elements do not relate to Due Diligence.

51. Why is the preparation of people in an organisation important in the process of invention generation?

- a) People should be encouraged and supported in the creation process
- b) Mistakes should be identified in the process
- c) It will help people better identify (nano) technology’s potential benefits
- d) None of the others

CORRECTION: The right answer is “People should be encouraged and supported in the creation process”. Identification of mistakes is important during the implementation process. During invention generation, the number of ideas is the most important factor.

52. What is there among the sources of potential ideas and inventions in an organisation?

- a) Customer needs and behaviours, supplier partnerships and marketing processes
- b) There exists a very narrow list of sources of potential ideas, so a company should refer to R&D institutions
- c) Only customer needs and behaviours – this is a basic concept for idea generation
- d) None of the others

CORRECTION: The right answer is “Customer needs and behaviours, supplier partnerships and marketing processes”. The list of sources is very broad and almost every part of each organisation can add something positive.

53. Schein’s concept of organisational culture means that culture...

- a) ... is generated not only by sharing values and traditions, but even more so by sharing assumptions
- b) ... is generated only by sharing values and traditions
- c) ... is not generated by employees, but only by owners
- d) ... is not generated by employees, but only by R&D institutions

CORRECTION: The right answer is “... is generated not only by sharing values and traditions, but even more so by sharing assumptions”, which may involve both employees and owners.

54. What is one of the advantages of decentralisation?

- a) Speeding up operational decisions by enabling line units to take local actions
- b) Decentralisation requires greater coordination by senior management, in order to ensure that individual units in the organisation are not working against the interests of the whole
- c) Decentralisation can encourage egotistical attitudes
- d) None of the others

CORRECTION: The right answer is “Speeding up operational decisions by enabling line units to take local actions”. The other options are not advantages of decentralization and may rather be regarded as potential drawbacks.

Case study-like questions

1. You are a group of scientists working at an university. You, as a team, have created a new nanotechnology product. You are thinking about its commercialization. You believe it will be a success and bring profits. You have no experience in doing business (none of you has ever created nor managed any company before). You would like to start your own business. What will be your first moves and why?
 - a) You, as a team of scientists, open a private start-up company and assess the commercial potential of your technology. If it shows there is a market for your technology, you start to prepare and then implement the business plan
 - b) You check the intellectual property status. You talk to your university authorities to protect the technology with a patent. You cooperate with the Technology Transfer Center in assessing the commercial potential of your technology. You find financial investors and other necessary partners and finally open the start-up company (spin-off)
 - c) You publish the research results as soon as possible and, as a team, look for a company that would be interested in buying the technology. If you find a buyer, then you sell the technology
 - d) You contact the Technology Transfer Center at your university to assess the commercial potential of the technology and to find partners for commercialization. You, as a team of scientists, open your own private business. After that, you protect your technology with a patent by using your own capital

CORRECTION: The right answer is “You check the intellectual property status. You talk to your university authorities to protect the technology with a patent. You cooperate with the Technology Transfer Center in assessing the commercial potential of your technology. You find financial investors and other necessary partners and finally open the start-up company (spin-off)”. When thinking about technology commercialization, first of all you need to make sure who the owners of the technology are, so you need to check the intellectual property status. If you want to commercialize your technology, you need to protect it. It is important to protect it legally, especially in the case of nanotechnology, where research is expensive

and time consuming. Because you have no experience in business management and you have never had your own business, it is worth cooperating with the Technology Transfer Center at your university. They will help you assess the commercial potential, find financial investors or other partners, prepare a good business plan or even establish a spin-off company. If you are scientists and worked to create the technology at your university, the members of your team are not the only co-owners of the technology. The university also owns part of the intellectual property. It means you need to make an agreement with the university authorities to use the technology for commercial purposes. The university may be interested in patenting the technology and opening a spin-off company. It may not be interested in commercialization and then you need to negotiate the possibility to commercialize the technology.

2. Marketing innovative products is often Business-to-Business (B2B) marketing which sees companies as your customers, selling on goods and services and being part of the supply chain or distribution channel. B2B markets are characterized by:
- more complex decisions
 - more rational buyers
 - limited number of customers
 - more complex products
 - more demanding buyers

This complexity and dynamism of B2B markets has implications for marketing communication. The target audiences for B2B communications are made of groups of constantly changing individuals with different interests and motivations. Faced with a multifaceted and knowledgeable buyer, it is critical that the B2B marketer demonstrates a high level of expertise in all interactions with the target audience. Personal relationships are more important and trust and security are key issues. This, in turn, places great emphasis on brand, reputation, case studies and other factors which convey reliability and consistency over the life of the product or service being purchased.

Source: B2B International, available at [16/02/2017]: <https://www.b2binternational.com/publications/b2b-marketing/>

Imagine you are a member of an university team that invented a solution based on nano-silver. A quick look report indicated that producers of cleaning products for animals (particularly horses) might be potentially interested in your innovation. Your innovation has been patented and does not require any more tests. It is ready to be sold. Please indicate which promotion tool would be best to communicate your innovation benefits to potential customers.

- a) TV and cinema advertising
- b) Direct sales
- c) Outdoor
- d) None of the others

CORRECTION: The right answer is “Direct sales”. This marketing communication tool is based on building direct relationships with potential customers. This includes phone calls, emails, trade meetings, product presentations etc. It is a very good tool for B2B markets where the number of potential customers is limited, decisions are more complex and transactions involve the transfer of knowledge and price negotiations. It also allows you to build personal relationships and long-term partnerships. Advertising is a mass communication tool that works better to reach big numbers of final consumers on the B2C market. It could be used later, by the producer of the products, to advertise that the new products include nano-silver to owners of animals. Outdoor is a mass communication tool that works better to reach big numbers of final consumers on the B2C market. It can be used on B2B markets when the number of companies from the target group (potential customers) becomes big. In this case, it could be used later, by the producer of the products, to promote that the new innovative product includes nano-silver to the owners of horses.

3. A pharmaceutical company is planning to introduce to the market a generic medicinal product that aims at treating certain allergies. Having studied various ways of applying the product, the team concluded that a nasal application in the form of a subtle mist would be best. They designed a nebuliser and carried out some laboratory tests. The nebuliser has a special nozzle design that conveys a more effective delivery, by precisely forming tiny droplets of uniform size and speed to reach the optimal location inside the nose, thus allowing for better absorption. The pumping system has also been improved so that it delivers a fixed, precise dose of the product, sufficient to treat symptoms for a whole day. For these reasons, the team thinks it could become a market leader. The team showed a prototype of the sprayer to one of the engineering companies from the university’s technology park. In collaboration with this company, they came up with an attractive design for the overall sprayer can, which is suitable for commercialisation. The design is minimal - "clean and clinical" - and comprises a white can with a single green button.

Can any of the IP elements in this project be protected by trade secret?

- a) Yes, the nozzle can be protected by trade secret
- b) No, but the project IP can be protected in other forms than a trade secret
- c) Yes, the pumping system can be protected by trade secret
- d) None of the others

CORRECTION: The right answer is “No, but the project IP can be protected in other forms than a trade secret”. The nozzle is a visible part of the product and can be easily replicated by competitors. The pumping system is a mechanical part of the product and can be easily identified, analysed and replicated by competitors.

4. During “phase X” of innovative project development, a company is looking for funds for product development, some initial marketing and some administrative overheads. The financing of this stage is usually offered to recently established companies or to those that have been in business for a short time, but not yet sold their product into the marketplace. Usually, companies in this stage will have

assembled key management, prepared a proper business plan and conducted an overall check on the market viability of their product or service being developed.

What is “phase X” of innovative project development and which of the sources of finance would you consider to be appropriate?

- a) Start-up phase and Business Angels financing
- b) Seed stage and Venture Capital fund financing
- c) Early growth phase and financing via bank loan
- d) All of the others

CORRECTION: The right answer is “Start-up phase and Business Angels financing”. The seed stage is related to projects that are not yet organised. They focus mainly on business model development and technical aspects of future products / services. In this case, financing by VC funds is very uncommon. The early growth phase is related to companies that have already started their products / services operations. A company in this phase may experience problems in obtaining a bank loan, i.e. due to a lack of income.