Lesson 1 – Introduction

1. What are 1 nm and 1 Å equal to in m?
2. What is the topic of nanotechnology?
3. What makes the Lycurgus Cup typical?
4. How is it possible that in the case of stained glass, gold does not have its typical yellow colour? What influences its colour?
5. What are nanostructures?
6. Name 4 types of the nanostructure with at least one example for each type.
7. Why is the size of nanostructures important?
8. What is a nanocomposite and what are its advantages? Give 2 examples of a nanocomposite.
9. Characterise 2 approaches in nanostructure fabrication.
10. Which approach to fabricating nanostructures is typical in microelectronics and which in biological systems?

Lesson 2a – Nanomaterial Characterisation I

1. Define when 2 points of an image can be perceived as resolved.
2. How can we calculate the size of the Airy disk and what measurement parameters must we choose for maximum resolution?
3. What limits the resolution in the case of optical and electron microscopy?
4. What do we mean by depth of field?
5. How does laser confocal microscopy work?
6. What quantities does the electron wavelength depend on if an electric field is used to accelerate it?
7. Compare SEM and TEM in terms of accelerating voltage, resolution, and sample requirements.
8. What can we measure with Dynamic light scattering (DLS)?
9. What field is used to accelerate electrons in an electron microscope? What field do we use to focus them and what force is applied to them during the focussing?
10. What requirements does a classical SEM have on the measured samples? What method can be used to image biological samples?

Lesson 2b – Nanomaterial Characterisation II

1. What requirements does the STM method have on the sample and what information does it provide?
2. How does AFM work? Is its resolution higher or lower than STM's?
3. What modes can the AFM method operate in and what distinguishes them?
4. On what physical principle is the XPS method based? What is its advantage over the EDX method?
5. Which physical quantity do we measure in XPS and which do we calculate and use for elemental analysis?
6. What physical law is the XRD method based on and what information does it give us about the measured material?
7. Why do we use X-rays in the case of the XRD method and not, for example, infrared radiation?

8. Based on the ratio of which two quantities are particles separated in mass spectrometry?
9. Which particles do we use in RBS technique and which quantity do we measure in them?
10. Why are thermodynamic methods not suitable for studying all nanostructures?

Lesson 3 – Photonics

1. What does an electron need to do to emit an electromagnetic wave?
2. What does photonics deal with?
3. What is a surface plasmon?
4. Why is it beneficial to use surface plasmon in electronics?
5. How is a localized surface plasmon formed?
6. Where have localized surface plasmons been used (unknowingly) in the history?
7. What advantage have localized surface plasmons brought to Raman spectroscopy?
8. What is a photonic crystal?
9. What accounts for the distinctive iridescent colours of many species of butterflies, insects, bird feathers, or opals?
10. Name at least 3 different types of X-chromic materials.

Lesson 4 – Magnetism

1. What are the two strongest sources of magnetic moment?
2. Sketch the arrangement of spins in diamagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic substances.
3. What are the macroscopic regions of solids with the same direction of magnetization called?
4. What is at the interface between two adjacent macroscopic regions with the same direction of magnetization? What happens to this interface when the substance is subjected to an external magnetic field?
5. Outline the hysteresis loop for a magnetically hard and a magnetically soft material (ferrite). Label the position of the residual induction and the coercive magnetic field strength in the figure.
6. What happens to a permanent magnet if it is heated above the Curie temperature?
7. What happens to the magnetic coercivity (the ability of a material to resist demagnetization by an external magnetic field) of a ferromagnetic particle if we reduce its size below the dimensions of a separate magnetic domain and why? What is this phenomenon called?
8. What is the shape of magnetic particles used for magnetic data storage? Name at least two applications of magnetic nanoparticles.
9. What is the name of the magnetic phenomenon used by the read heads of most current hard drives? Outline a structure on which this phenomenon can be observed.
10. What is the focus of spintronics?

Lesson 5 – Electronics

1. How do the energy bands of semiconductors and insulators differ?
2. What is the point of adding impurities into intrinsic semiconductors?
3. If a P-type and an N-type semiconductor are touching each other, how does the concentration of free charges at the resulting interface change?

4. What is the name of an electronic component that uses external photons entering the P-N junction to form electron-hole pairs?
5. What do a triode and a transistor have in common, given their function?
6. How does the gate (G-gate) in a MOSFET transistor affect the conduction bridge between the source (S) and drain (D) electrodes of the transistor?
7. What are the logic gates inside current microprocessors made of?
8. Name at least three problems we face in further shrinking semiconductor structures in microelectronics?
9. Is it possible to synthesize a chemical molecule capable of independently directing the flow of electric current? What is the name of the branch of science that deals with this problem?
10. Where are nanotubes or nanowires located in a FET transistor?

Lesson 6 – MEMS, NEMS

1. What are MEMS and NEMS?
2. Name 3 basic consecutive steps of lithographic micromachining.
3. Draw a typical etch profile for isotropic and anisotropic etching.
4. Which method of MEMS structures fabricating is characterized by the presence of sacrificial material? What is its function?
5. List at least 3 different techniques for nanofabrication (fabrication of NEMS structures).
6. Describe the principle of nanoprinting.
7. What is the difference between SPM induced oxidation and SPM lithography?
8. What is the principle of operation of a MEMS gyroscope?
9. Where is the MEMS component located in a DLP projector? What is it used for?
10. Describe the 3 basic options for pumping fluids in microfluidic systems.

Lesson 7 – Carbon Nanostructures

1. What type of orbital binds the carbon atoms of graphite in the plane of the graphene structure and what type of orbital is oriented perpendicular to this plane?
2. Diamond and graphite - which one is an electrical conductor and which one is an insulator?
3. What are spherical carbon molecules called?
4. What is the difference between exohedral and endohedral fullerene?
5. Name at least two different processes for making carbon nanotubes.
6. What is the name of the vector that determines the way the graphene wall is rolled and consequently the type of electrical conductivity of the carbon nanotubes?
7. Name at least 3 possible applications of carbon nanotubes.
8. What are some ways in which graphene is produced? Describe at least 3.
9. Is graphene an electrical conductor or insulator?
10. Why is graphene useful as a detector in chemical and optical sensors?

Lesson 8 – Infrastructure and Environment

1. What is concrete made of?
2. Is concrete strongest in compression, tension, or bending?
3. Outline and comment on the stress-strain curve of concrete.

4. How can we use nanotechnology to increase the mechanical strength of concrete?
5. How can we use nanotechnology to prevent corrosion of iron reinforcement in reinforced concrete.
6. What are the 2 different types of self-repairing concrete. Briefly describe both types.
7. What are the 3 types of water purification in terms of treatment character?
8. What are the uses of environmental nanotechnology?
9. How can we use nanotechnology for water purification? Write at least 3 possibilities.
10. What types of plant-based soil remediation do we know? Describe both of them briefly.

Lesson 9 – Nanocatalysis and Energy

1. What is the difference between homogeneous and heterogeneous catalysis?
2. Can the choice of catalyst affect the resulting type of the chemical product?
3. Why is it beneficial in most cases for the catalyst to be in the form of small particles?
4. How can the aggregation (clumping) of nanoparticle catalysts be prevented in heterogeneous catalysis so that their active surface area cannot be reduced?
5. Which molecule is often referred to as the fuel of the future because it could replace current hydrocarbons? How can this molecule be produced?
6. On which electrode is UV light incident during photocatalytic hydrogen production? On the metal or on the semiconductor one?
7. What are hydrogen fuel cells used for? What advantage does it provide?
8. What is the main cause of slow charging and discharging of electric batteries? How can this shortcoming be addressed using nanotechnology?
9. How can we generate energy from waste heat? What is the name of this phenomenon? Where is this used?
10. How can we produce energy from vibrations in the environment? What is the name of this phenomenon? What are the possible applications?

Lesson 10 – Bionanotechnology

1. Which physical law keeps small objects in the focus of the laser beam of an optical tweezer?
2. Does DNA origami represent a bottom-up or top-down technology?
3. What is the focus of biomimetics?
4. Briefly describe (or outline) the microstructure of a mussel shell that accounts for its extraordinary strength.
5. What is the lotus effect? Where can this effect be applied in practical applications?
6. Name the force responsible for the adhesion of the lamellae on gecko’s feet to the surface?
7. Why is it necessary for the gecko foot lamellae to be both fine and dense?
8. What is nanoencapsulation?
9. Name at least 3 areas of research currently being addressed by medical nanotechnology.
10. On which nanotechnologies can we base an electronic skin on?