Summerschool 2014

Nanophysics

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For numerical applications one may (crudely) assume the following values:
Reduced Planck constant hbar=h/2π=10^{-34} S.I.
Electron charge e=10^{-19} C
Boltzmann constant k_B=10^{-23} J/K

1. In quantum mechanics, the uncertainty relation relates the possible precision of the measurement outcome of position to that of
   a.) angular momentum
   b.) energy
   c.) momentum
   d.) frequency

2. The orbital wave function of an electron of mass m is assumed to be a plane wave travelling along z, with wave vector k. The probability of finding the electron is
   a.) position independent
   b.) maximum every $2\pi / k$ along z
   c.) maximum every $\pi / 2k$ along z
   d.) maximum at position z = hbar k z / m

3. Discretization of allowed energies for the orbital modes of a quantum system requires
   a.) a finite wave function
   b.) low enough temperatures
   c.) one scattering boundary
   d.) two scattering boundaries

4. The energy levels of the hydrogen atom are given by -13.6/n^2 eV. What temperature is required to obtain a significant thermal population of level n=2 ?
   a.) 1,000 K
   b.) 10,000 K
   c.) 100,000 K
   d.) 1,000,000 K

5. The tunneling current between an STM tip and a substrate is given by
   $I \propto \exp(-z/z_0) \times \int \rho_S(E-eV)dE$,
   where zero temperature and a constant density of states in the tip are assumed. The integration boundaries are not important for this question, ρ_S is the sample density of states, z the tip-sample distance, z_0=0.1 nm, V the applied voltage. The tip is scanning at a given height z above a perfectly flat area, of homogeneous density of states ρ_S. At some point, ρ_S increases by a factor of 2 at all energies. By how much does the scanning height z of the tip change, assuming constant current is maintained?
   a.) $z_0/2$ up
   b.) z_0 ln(2) up
   c.) $z_0/2$ down
   d.) z_0 ln(2) down

6. A small resonator of mass m=1 μg has a resonant frequency of 1 MHz. A single molecule, of mass $(1/\pi)*10^{-20}$ kg, is deposited on the resonator. The resonant frequency changes by
   a.) 10 Hz
   b.) 0.1 Hz
   c.) 0.001 Hz
   d.) 0.00001 Hz

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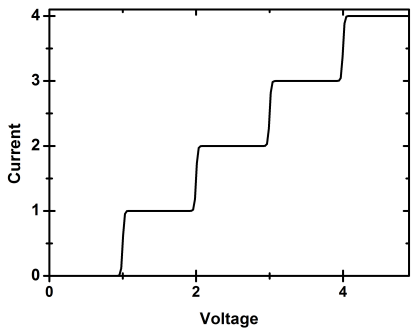
7. Assume an object is attached to the above resonator, inducing a change in the resonant frequency by 0.01 Hz. What is the minimum required quality factor of the resonator as to be experimentally able to detect this extra load?
   a.) 10^4
   b.) 10^6
   c.) 10^8
   d.) 10^{10}

8. Assume an interaction potential between a sample and an AFM tip given by $U \propto z^{-3}$, where z is the tip-sample distance.
   The frequency change of an AFM cantilever close to a surface is then proportional to
   a.) z^{-5}
   b.) z^{-4}
   c.) z^{-3}
   d.) z^{-2}

9. If you were to observe the above height dependence of the interaction potential and you knew your tip is very blunt, which kind of interaction would you suspect to be at play?
   a.) electrostatic
   b.) van der Waals
   c.) Casimir
   d.) work function difference

10. Below is shown the current vs. voltage characteristic acquired by a STM tip on top of an unknown conductive object. Based on this measurement, would you conclude that the object is
   a.) a harmonic oscillator like quantum dot
   b.) a hydrogen atom like quantum dot
   c.) a bulk three-dimensional conductor
   d.) a bulk two-dimensional conductor



Nano-devices and Nano-electronics

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1) Which of the following is the most accurate description of "Analog Design"?

a) The skill to design and implement electronic systems to process information and make computation.
b) The skill to design and implement electronic systems which interact with electrical signals with real value.
c) The skill to use solid-state devices to construct processing and computing systems

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2) What is a typical channel length (gate length) dimension that can be found in mainstream CMOS technology in 2014?

a) 28 nanometers
b) 90 nanometers
c) 45 micrometers

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3) In an analog to digital converter, generally which part consumes the most ?

a) Digital post processing
b) Sampler
c) Comparator

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4) In an radio receiver, which parameter is the most critical one to achieve a desired sensitivity ?

a) linearity
b) power dissipation
c) noise

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5) The most critical parameter in a transistor that defines the performance is:

a) having lower parasitic elements, such as parasitic capacitance
b) having higher transconductance
c) having smaller size

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6) Which type of ADC do you choose when energy dissipation is the main issue ?

a) SAR ADC (successive approximation register ADC)
b) Sigma-Delta ADC
c) Pipelined ADC

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7) Which type of ADC generally produces the highest data rate?

a) SAR ADC (successive approximation register ADC)
b) Sigma-Delta ADC
c) Pipelined ADC

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8) In a flash ADC, how many comparators are required to construct an N-bit converter?

a) 1
b) 2^N-1
c) N
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9) What is the typical voltage gain that a one stage amplifier can provide?

a) less than 10
b) more than 10
c) more than 10 only in very advance technology node
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10) How do you construct a low pass filter?

a) 1x series capacitor followed by a parallel inductor
b) 1x series capacitor followed by a parallel resistor
c) 1x series inductor followed by a parallel capacitor

C

Carbon-based nanomaterials

1.	The carrier transport in grapheme goes through π-bands that are resulted from …	☐ sp^2 hybridization of valence electrons
		☐ sp^3 hybridization of valence electrons
		☐ unhybridized *s*-orbital valence electrons
		☐ unhybridized *p*-orbital valence electrons
2.	The kinetic energy of electrons in monolayer grapheme is proportional to …	☐ the value of wavevector, k
		☐ the square value of wavevector, k^2
		☐ the value of electron effective mass, m^*
		☐ the reciprocal value of electron effective mass, $1/m^*$
3.	What does the "chirality" (n,m) denote for carbon nanotubes (CNT)?	☐ If the CNT is single-walled or multi-walled
		☐ If the CNT is insulating or metallic
		☐ A direction that the graphene sheet is rolled up to form a tube
		☐ A direction that the CNT extends along
4.	If a single-walled CNT is semicon-ducting, the bandgap scales with …	☐ the value of diameter, d
		☐ the square value of diameter, d^2
		☐ the reciprocal value of diameter, $1/d$
		☐ the reciprocal square value of diameter, $1/d^2$

5. Fullerene molecule is … **C**	☐ a cluster of 60 carbon atoms all bonded with sp^3 hybrids ☐ a shell of 60 carbon atoms all bonded with sp^2 hybrids ☐ a complex of 60 carbon atoms bonded with mixture of sp^2 and sp^3 hybrids ☐ a ball shape of 60 carbon atoms bonded with 2*p* valence electrons
6. Graphene epitaxial growth by thermal annealing of SiC is completed by …	☐ segregation to condense a carbon layer on top of the surface ☐ silicon sublimation during annealing, while carbon atoms remain on the surface ☐ an oxidation process to remove silicon atoms ☐ a reduction process to rearrange carbon atoms on the surface
7. As a possible solution for future CMOS technology, why graphene FETs are more favored than CNT-FETs?	☐ Because grapheme FETs are more suitable for large area processed using existing technology ☐ Because grapphene FETs can bring to ballistic transport ☐ Because grapheme FETs have a larger current handing capability ☐ Because graphene FETs have a higher on/off current ratio

8. CNTs process a very high Young's modulus, due to …	☐ 4 valence electronic bonds of carbon atoms that equally share stress in any directions
	☐ a perfect construction in tubular form
	☐ the covalent sp^2 bonds formed between the individual carbon atoms
	☐ delocalized π-electrons that travel across several carbon atoms to increase strength

NANOBIO and MICROSYSTEMS

1-Lipid vesicles (or liposomes) can :

A) store a hydrophilic molecule in their core
B) store a hydrophobic molecule in their lipid shell
C) store a hydrophilic molecule in their lipid shell

B

2-Please cite 2 anti-cancerous agents

A) Paxlitaxel
B) Insulin
C) Doxorubicin
D) Polyglutamic acid

3. How is it possible to specifically target a cell using liposomes ?

A by grafting a ligand on the liposome that can target a specific cellular receptor, for instance ERB receptor
B by incorporating a protein inside the liposome core
C. by selecting lipids that can interact with the cell

4. What is the "Enhanced Permeability and retention (EPR) effect?

A the retention of the nanoparticules inside the vessel wall
B an enhanced permeability of the vessel wall at the tumor site due to an abnormal organization of the endothelium
C. the enhancement of life time of the nanoparticles in the blood flow

5-Polymeric nanoparticles are attractive systems in the field of biomaterials :

A for the targeted delivery of drugs
B for orthopedic applications
C as cell carrier

6-How is a lipid cell membrane organized ?

A. A bilayer of phospholipids
B. A monolayer of hydrophobic lipids
C. A bilayer of single chain lipids

7.-The lipid bilayer :

A. Has an inner hydrophilic core and its external part is also hydrophilic
B. Has an inner hydrophobic core and its external part is hydrophilic
C. Has an inner hydrophilic core and its external part is hydrophobic
D. Has an inner hydrophobic core and its external part is also hydrophobic

8- The following proteins are extra-cellular matrix proteins:

A collagen
B microtubules
C fibronectin
D vimentin

9-The following molecules are hydrophilic :

A polysaccharides
B polyethylene glycol (PEG)
C the tail of phospholipids

10-Cell adhesion to the extracellular matrix

a) Is mediated by specific trimeric transmembrane receptors
b) Is mostly mediated by heterodimeric receptors called integrins

c) Is mediated by receptors that are highly specific for one type of matrix protein
d) Is mostly due to hydrophobic interactions with the substrate

11-What is microcontact printing ?

A printing a protein on a substrate
B printing a non adhesive molecule on a substrate
C printing a protein by a laser

B

12-How can a cell adapt to a substrate presenting a nanotopography ?

A. It can possibly change its spreading area
B. It can possibly form focal contacts
C. The organization of its cytoskeleton may change
D. Lipids can leak out of the membrane

13. Cell adhesion to the extracellular matrix

A Is mediated by specific trimeric transmembrane receptors
B Is mostly mediated by hetero dimeric receptors
C Is mediated by receptors that are highly specific for one type of matrix protein
D Is mostly due to hydrophobic interactions with the substrate

14- Today, artificial retina contain :

A) About 20 electrodes
B) Several hundred of electrodes
C) Several thousand of electrodes

15- To place a pacemaker, the surgeon needs to :

A) Pass the electrodes through a vein in order to reach the inside ventricula
B) Introduce the electrodes through the tissue covering the heart and put them in contact with external ventricula
C) Implant the electrodes under the skin above the heart

16. To master the bioMEMS technology, one needs to :

A) Master microelectronics
B) Master macrotechniques
C) Master silicon micromachining technologies
D) Master mathematics

17-Microsensors to identify finger prints :

A) Can be based on resistive measurements
B) Can be based on capacitive measurements
C) Are only 50 % reliable
D) Need more than 100 identification points in order to get a reliable measurement

18. Among the clinical needs listed below, which ones do apply to the artificial heart developped by the CARMAT company ?

A) Shape, weight, volume of the artificial heart
B) Compatibility with blood
C) Efficacy, durability at least equivalent to that of a graft
D) Delivery of an active molecule

19. The first patient who got the first artificial heart from CARMAT in Dec 2013 :

A Is still alive
B died in February 2014

20. To what category of materials does Si3N4 belong, which is used to coat the tip of cantilevers ?

A a metal
B an insulator
C a semiconductor

B