Summerschool 2013
**Nanophysics exam**

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For numerical applications we will (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
Gravitational acceleration on earth g=10 m.s$^{-2}$

1.  In quantum mechanics, $\hbar$ relates energy to the
    a.) wave vector
    b.) position
    c.) momentum
    d.) frequency

2.  What are the standard international units of the orbital wave function of an electron?
    a.) m$^{-3/2}$
    b.) m$^{-3}$
    c.) m.s$^{-1}$
    d.) no units

3.  For a given electronic orbital wave function ψ(r), the physical meaning of $|\psi|^2$ is
    a.) the density of states at position r
    b.) the density of charge at position r
    c.) the density of probability of presence at position r
    d.) the probability for the electron to exist

4.  If a particle's position is defined with good precision around position $r_0$, which other quantity is then necessarily poorly defined?
    a.) mass
    b.) energy
    c.) time of residence around $r_0$
    d.) momentum.

5.  The Fermi-Dirac distribution in a solid conductor describes
    a.) the spacing between adjacent energy levels
    b.) the way electrons pile up in energy space
    c.) the probability of presence in real space
    d.) the density of states

6.  An STM tip is placed 0.5 nm above a conductive surface, at a given bias voltage. The tunnel current is 10 nA. The tip is then moved away from the surface by 0.2 nm; the current drops to 1 nA. At what distance to the surface will the current go below 1 pA?
    a.) 1.7 nm
    b.) 1.5 nm
    c.) 1.3 nm
    d.) 1.1 nm

7. A small cantilever is oscillating along direction z. As its approaches a surface exerting some conservative force F along, the oscillators resonant frequency changes proportionally to
a.) $F^2$
b.) F
c.) 1/F
d.) dF/dz

8. Germanium has a semiconducting gap of 0.6 eV. Convert this energy into temperature.
a.) 5000 K
b.) 5 K
c.) 50000 K
d.) 500 K.

9. Why is atom manipulation by STM necessarily taking place at very low temperatures?
a.) To avoid atom diffusion on surface
b.) To make sure the tip is in a quantum state
c.) To increase the charging energy of the atom
d.) To limit Casimir forces

10. The van der Waals force between two spheres is given by the following expression
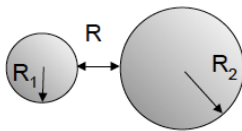


$$F = -\frac{R_1 R_2}{R_1 + R_2} \frac{H}{6R^2}$$ Assume a vertically hanging chain of N adjacent spheres with radius 10 nm each, separated by 1 nm, and of mass $10^{-21}$ kg each. How big can N be before the first bond breaks due to gravity? (H = 1 eV)
a.) about 10,000
b.) about 10,000,000
c.) about 10,000,000,000
d.) about 10,000,000,000,000

11. The differential conductance of a tunnel barrier between a metallic tip and a semiconducting sample surface is a measure of
a.) the Fermi-Dirac distribution of the sample
b.) the density of states in the sample
c.) the electronic density in the sample
d.) the resistance of the sample

12. Two parallel mirrors separated by a distance R feel an attractive force proportional to $1/R^4$. This force is named
a.) van der Waals force
b.) Casimir force
c.) Debye force
d.) the dark force.