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QS^3 2018 Question Session 1

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Test of Response System

Question 1

Does this response system work correctly?

A. Yes

B. No

Overview of Quantum Materials

Question 2

Why is symmetry important for understanding Quantum Materials?

1. It is persistent and only changes in a phase transition
2. It leads to order parameters that can not be adiabatically removed
3. It implies quantum numbers and degeneracies
4. It allows the use of group theory to analyze / categorize systems

A) 1 and 3
B) 2 and 3
C) 1, 2, and 3
D) 1, 3, and 4
E) All of the above

Overview of Quantum Materials

Question 3

A Quantum Spin Liquid can host a fractional quantum number by:

1. Spontaneously breaking lattice symmetries to create multiple interacting quantum systems
2. Separating an excitation in to pairs which act locally as spin ½ objects
3. Pair-creating quarks out of the frustrated atomic nuclei
4. Macroscopically aligning moments to lead to a fractional order parameter

A) 1
B) 2
C) 3
D) 4
E) None of the Above

Density Functional Theory

Question 4

What are some of the advantages which make density functional theory (DFT) useful?

1. It can, in principle, calculate the exact many-body wavefunctions of the electrons in a material
2. It can, in principle, calculate the ground state energy of the electrons in a material
3. It can, in principle, calculate the exact excitation spectrum of the electrons in a material

A) None of the above
B) 1 only
C) 2 only
D) 2 and 3
E) All of the above

Density Functional Theory

Question 5

Which of the following are true about density functional theory?

1. When performing calculations, DFT calculations does not need to employ electronic wavefunctions – it solely uses the density of electrons *n*(r)

2. If the correct "*exchange correlation potential*", V_{xc}, could be written down, then it is, in principle, possible to calculate the exact ground state energy and density of the electronic system

3. It is possible to easily perform calculations on completely amorphous (i.e. disordered) systems

A) 1 and 3
B) 1 only
C) 2 only
D) 1 and 2
E) 2 and 3

Scanning Tunneling Microscopy

Question 6

Which of the following samples could likely be measured successfully (i.e. atomically resolved topographs and spectroscopic imaging) in a scanning tunneling microscope?

1. 20 nm epitaxial thin films of sapphire
2. Single crystals of the high-temperature superconductor Bi2Sr2CaCuO8
3. Single crystals of the cubic perovskite ferromagnet SrRuO3
4. A monolayer of graphene grown on a doped SiC substrate
5. Polycrystalline samples of La2-xSrxMnO3

A) 1, 2, and 3
B) 2 and 4
C) 2, 3, and 4
D) 2, 3, 4, and 5
E) All of the samples

Scanning Tunneling Microscopy

Question 7

The dI/dV spectrum taken by spectroscopic imaging STM is exactly proportional to the local density of states (DOS) of a material taken at that spatial position.

A) True
B) False
C) It depends

Scanning Transmission Electron Microscopy

Question 8

The information in scanning transmission electron microscopy can be used to directly determine :

1. The mobility and mobile carrier density of a two-dimensional electron gas
2. Magnetic textures in a skyrmion lattice
3. The electric polarization in multiferroic $BiFeO_3$
4. Single atomic defects in a monolayer transition metal dichalcogenide
5. The strength of electron-phonon coupling in a charge density wave system

A) 1, 2, 3, and 4
B) 1, 3, and 4
C) 3 and 4
D) 2, 3, and 4
E) All of them

Synthesis of Quantum Materials

Question 9

Which of the following are useful for improving solid state reactions?

1. Centrifuging materials to orient / grade grain size
2. Repeated regrinding and refiring of material
3. Spraying acetone in to the powders

A) None of the above
B) 1 and 2
C) 2 and 3
D) 1 and 3
E) All of the above

Synthesis of Quantum Materials

Question 10

Merits of high pressure synthesis are:

1. Increased reaction rates
2. Stabilization of incongruent melt transitions
3. Stabilization of low symmetry phases

A) 1 only
B) 2 only
C) 3 only
D) 1 and 3
E) 2 and 3

Angle-Resolved Photoemission Spectroscopy

Question 11

Angle-resolved photoemission spectroscopy (ARPES) would, in principle, be a suitable tool for determining :

1. The momentum anisotropy of the superconducting gap in a two-dimensional, high-T_c superconductor
2. The spin configuration of an antiferromagnetic metal
3. The exciton binding energy in a semiconducting transition metal dichalcogenide
4. The electron-phonon coupling in a lightly-doped polaron liquid
5. The size of the band gap in a wide band gap insulator (e.g. quartz)

A) 1, 2, 3, and 4
B) 1, 2, and 3
C) 1 and 3
D) 1 and 4
E) All of them

Angle-Resolved Photoemission Spectroscopy

Question 12

Let's assume we wanted to use ARPES to determine the momentum dependence of the superconducting gap of a 2D superconductor with a T_c of 20 K. For such a measurement, we would ideally want the energy resolution, ΔE, of our ARPES spectrometer to be AT LEAST on the order of :

A) 1 eV
B) 100 meV
C) 10 meV
D) 1 meV
E) 0.1 meV