Ministry of higher education
Higher institute for engineering
and Technology
New Damietta
Course title: Ceramics

First Semester (Oct. 2017)
Midterm exam
Level five
Time allowed: 90 min
Full Mark: 20 Marks

Model Answer

Question No. 1 **[9 degree]**

a) Define what's mean by ceramics materials and its materials age? **[3 degree]**

Ceramics can be defined as solid compounds that are formed by the application of heat, and sometimes heat and pressure, comprising at least one metal and a nonmetallic elemental solid or a nonmetal; a combination of at least two nonmetallic elemental solids, or a combination of at least two nonmetallic elemental solids and a nonmetal

The material ages

Age	Period
Stone Age	~2,000,000 BC
Lower Paleolithic	1,500,000 BC
Upper Paleolithic	40,000 BC
Neolithic: (*Aceramic*) (*Ceramic*)	 8,500 BC 7,000 BC
(End of Ice Age)	8,000 BC
Chalcolithic	4,500 BC
Bronze Age	3,200 BC
Iron Age	1,200 BC
Concrete Age	200 BC
Steel Age	1850 AD
Silicon Age	1950 AD
New Materials Age (Polymers, composites, ceramics, Age..etc)	1990

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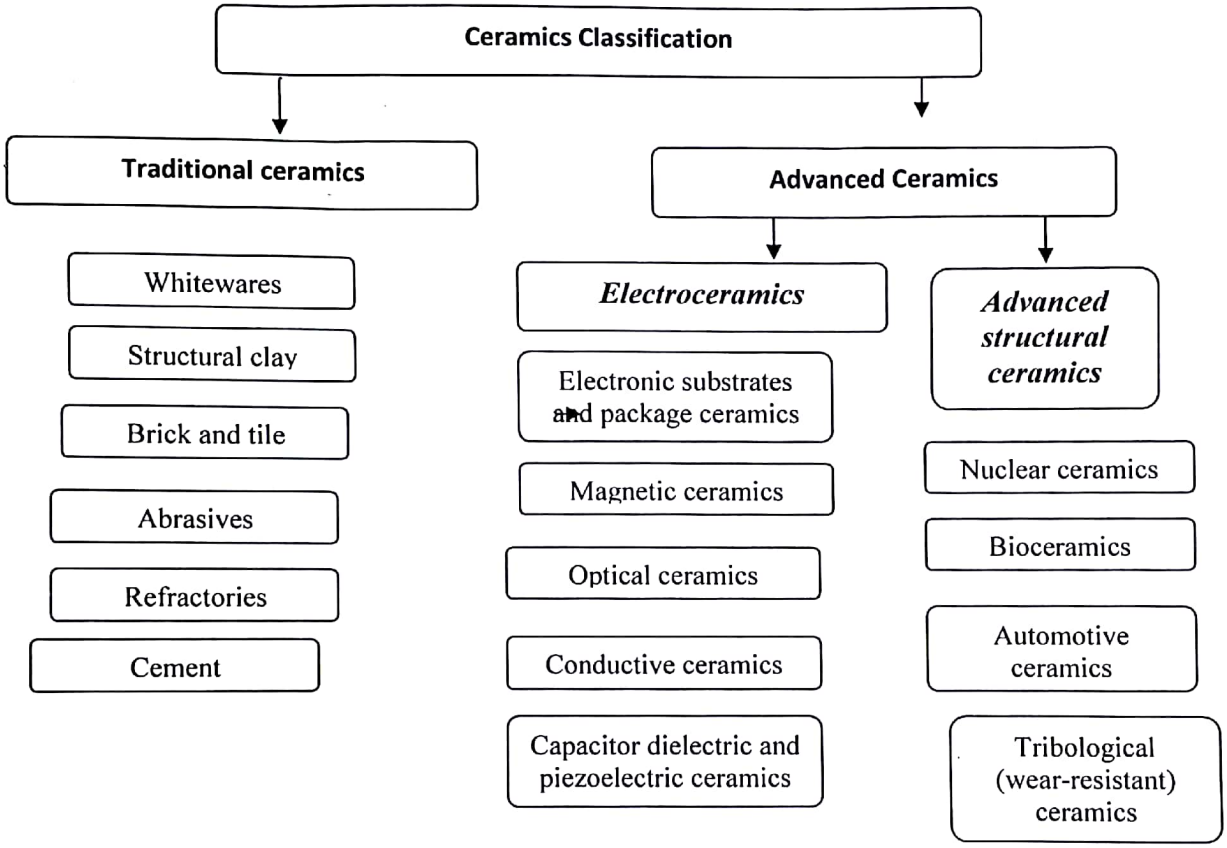
b) Classify ceramic materials? **[3 degree]**



c) Mentioned the progress in ceramic materials **[3 degree]**

Class of ceramics	Applications	Substances and characteristics
Conventional ceramics	Glasses, cements and porcelains	Silicates (SiO_2 as a main ingredient)
New ceramics	Refractory, polishing and cutting materials	Materials non-silicates
Fine ceramics	Electronic materials and precision machining tools	Compositional and microstuctural control

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Question No. 2 **[6 degree]**

a) Classify advanced ceramics according to properties and their applications? **[3 degree]**

Advanced Ceramics

- **Coarse**
  - Porous
    - Silica bricks
    - Forsterite bricks
    - Corundum bricks
    - SiC-bricks
    - Grinding wheels
  - Dense
    - Fusion casted
    - Bricks
- **Fine**
  - Porous
    - Grinding wheels
    - Filters
    - Oxides ceramics
    - Insulation parts
  - Dense
    - Oxides ceramics
    - Electric ceramics
    - Dental ceramics
    - Glass ceramics
    - Steatite ceramics
    - Graphite ceramics

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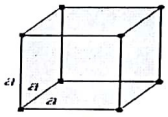
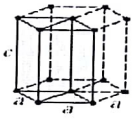
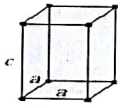
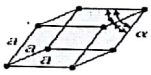
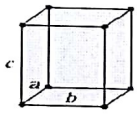
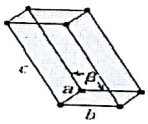
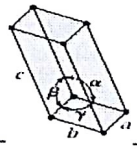
b) Illustrate the seven crystal systems? **[3 degree]**

the seven crystal systems [4].

Crystal System	*Axial Relationships*	*Interaxial Angles*	*Unit Cell Geometry*
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$	
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	

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Question No. 3 **[5 degree]**

Explain the different factors affecting the structure of ceramics.

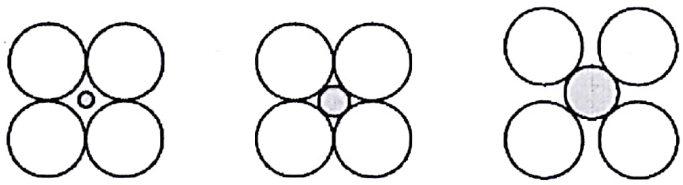
Three factors are critical in determining the structure of ceramic compound: crystal stoichiometry, the radius ratio, and the propensity for covalency and tetrahedral coordination.

1- Crystal Stoichiometry

Any crystal has to be electrical neutral; i.e., the sum of the positive charges must be balanced by an equal number of negative charges, a fact that is reflected in its chemical formula. For example, in alumina, every two Al^{3+} cations have to be balanced by three O^{2-} anions, hence the chemical formula Al_2O_3. This requirement places severe limitations on the type of structure the ions can assume. For instance, an AX_2 compound cannot crystallize in the rock salt structure because the stoichiometry of the latter is AX, and vice versa.

2- Radius Ratio

To achieve the state of lowest energy, the cations and anions will tend to maximize attractions and minimize repulsions. Attractions are maximized when each cation surrounds itself with as many anions as possible, with the proviso that neither the cations nor the anions "touch". To illustrate, consider the four anions surrounding cations of increasing radii as shown in figure . The atomic arrangement in figure (a) is not stable because of the obvious anion-anion repulsions. Figure c, however, is stabilized by the mutual attraction of the cation and the anions. When the anions are just touching (figure b), the configuration is termed *critically stable* and is used to calculate the critical radii at which one structure becomes unstable with respect to another.



(a) (b) (c)

Stability criteria used to determine critical radius ratios .

Since cations are usually smaller than anions, the crystal structure is usually determined by the maximum number of anions that it is possible to pack around the cations, which, for a given anion size, will increase as the size of the cation increases. Geometrically, this can be expressed in terms of radius ratio r_c/r_a. The critical radius for various coordination numbers. Even the smallest cation can be surrounded by two anions and results in a linear arrangement. As the size of the cation increases, i.e., as r_c/r_a increases, the number of anions that can be accommodated around a given cation increases to 3 and a triangular arrangement becomes stable . $r_c/r_a \geq 0.225$, tetrahedral arrangement becomes stable, and so forth.