University of Mumbai

No. UG/152 of 2019-20

CIRCULAR:-

Attention of the Principals of the Affiliated Colleges and Directors of the recognized Institutions in Faculty of Science & Technology.

They are hereby informed that the recommendations made by the Ad-hoc Board of Studies in Nano Science & Nano Technology at its meeting held on 12th April, 2019, have been accepted by the Academic Council at its meeting held on 15th April, 2019 **vide** item No. 4.37 and subsequently approved by the Management Council at its meeting held on 26th April, 2019 **vide** item No.19 and that in accordance therewith, in exercise of the powers conferred upon the Management Council under Section 74(4) of the Maharashtra Public Universities Act, 2016 (Mah. Act No. VI of 2017) the syllabus of Ph.D. Nanoscience & Nanotechnology (CBCS) has been introduced and the same have been brought into force with effect from the academic year **2015-16**, accordingly. (The same is available on the University's website www.mu.ac.in).

(Dr. Ajay Deshmukh)
REGISTRAR

MUMBAI – 400 032
22nd November, 2019

To,

The Principals of the affiliated Colleges and Directors of the recognized Institutions in Faculty of Science & Technology. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.37/15/04/2019
M.C/19/26/04/2019

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No. UG/152-A of 2019 MUMBAI-400 032 22nd November, 2019

Copy forwarded with Compliments for information to:-

1) The Dean, Faculty of Science & Technology,
2) The Chairman, Ad-hoc Board of Studies in Nano Science & Nano Technology,
3) The Director, Board of Examinations and Evaluation,
4) The Director, Board of Students Development,
5) The Co-ordinator, University Computerization Centre,

(Dr. Ajay Deshmukh)
REGISTRAR

Eligibility for admission to the Ph.D.(Nanoscience & Nanotechnology) :-

It was **resolved** that the syllabus of Ph. D. degree in Nanoscience and Nanotechnology, as per the UGC norms (copy enclosed) have been discussed in the meeting. Committee resolved to implement the said syllabus to the Ph.D. candidate registered in Nanoscience and Nanotechnology. This syllabus would also be post-facto implemented to the candidates who has already done the course work in the said line.

Eligibility for admission to the Ph.D.(Nanoscience & Nanotechnology) There are many queries about the eligibility for the admission to the Ph.D.(Nanoscience and Nanotechnology). Nanoscience and Nanotechnology is an interdisciplinary subject. Thus, committee resolved that the students apply for Ph.D. course in Nanoscience and Nanotechnology must have M.Sc. degree/ M.Phil. Degree in the following subject:-

a) Nanoscience & Nanotechnology, Physics,Chemistry, Life sciences, allied subject to Biophysics, Bio-Chemistry, Bio-technology, Micro-Biology etc.

b) Candidate having bachelor degree in Engineering, Technology or Pharmacy are also eligible for admission to Ph.D. (Nanoscience and Nanotechnology).

So, all the pending cases about topic approval due to eligibility criteria should be resolved using above mentioned guideline.

Ph.D. Course work for PhD degree Nanoscience and Nanotechnology (As per the UGC guidelines)

The coursework for the Ph. D. has been designed by the latest guidelines by the UGC for minimum standard for awards of M.Phil. and Ph.D. degree regulations 2016. Notified in the Gazette of India (No 28 part III section 4 for the week July 11-July 17, 2009)

1. Each candidate after having been admitted to the Ph.D. degree programme shall be required to undertake course work for a minimum period of one semester. The course work shall be treated as pre-Ph.D. preparation.

2. The Ph.D. course work shall be offered with credit system. The candidate will have to earn 16 credits in maximum of three semesters.

3. The candidate is allowed to take the advantage of **Credit Transfer** from other recognized university or the university department. In consultation of Board of Studies, the Director is authorized to allow the candidate to avail this facility on a case by case basis.
4. Course work will be handled by concerned guide/s in association with the academic coordinator of the center.

5. Seven point scale will be followed for assigning the final grade. Candidate should get minimum 'B+'grade to qualify.

6. After completion of the course work guiding teacher will submit the certificate of completion in following format.

7. The PhD candidate admitted in the other centers are also eligible to admit for this course with a prior consent from the Director NCNNUM and written permission of the HOD/ Director/Principal of the center.

National center for nanoscience and Nanotechnology, Mumbai University
This is to certify that Mr/Ms/Mrs……(Surname) ……(First name)…… (Second name)……..…… has been a regular student of Ph.D. with registration number ……He/She attended the course work conducted at the recognized research centre/department from ……to……. during the year …… He/She has successfully completed the Ph.D. course work prescribed by the University of Mumbai. He/She secured …grade in seven point scale.

Date:- Signature Guiding teacher Head of the Department/principal
Seal

The course structure is as follows :-

Paper title	Paper code	Maxcredits	Mode of evaluation
Research Methodology computational and mathematical applications	PHD-NANO-101	04	40% internal in form of quizzes, multiple choice questions 60% External in form of subjective question answers and numerical problems
Term review paper:-	PHD-NANO-102	04	50% review writing on the chosen topic (about 25 pages) 50% power point presentation
Optional Courses on specialized subjects	PHD-NANO-201 through PHD-NANO-208 Any two.	04	40% internal in form of quizzes, multiple choice questions 60% External in form of subjective question answers and numerical problems
Skill development:- Hands on training of highly sophisticated instrument Facility:Minimum 3 major instruments in span of 3 semester	PHD-NANO-301	04	Instruments assigned by center director. Handling and users training and samples running at least for 8 hours a week. It will be certified by the center director at end of the third semes*ter.

The Course and the corresponding detail syllabus is as follows:-

Compulsory Course I-(PHD-NANO-101) (4 credits, 60 Hours, (30 contact hours+ 30 non contact hours)

Research Methodology computational and mathematical applications

Unit I :- Scientific Research :- Research Definition, Characteristics, types, need of research. Identification of the problem, assessing the status of the problem, formulating the objectives, preparing design (experimental or otherwise), Actual investigation.

Unit II:- Literature survey :- References, Abstraction of a research paper, search engines viz. Scifinder scholar, Science Direct, Google scholar, Social sites in science research viz. research gate, Linkedin.

Unit III:- Documentation and scientific writing:-Preparation of manuscript, logical presentation of research articles for Publication of Research paper, Presenting a paper in scientific seminar, thesis writing. Structure and Components of Research Report,Types of Report :-research papers, thesis, Research Project Reports, Pictures and Graphs, citation styles, writing a review of paper, Bibliography.

Unit IV:- Use of program packages :- word processing, spreadsheet and database Software. Plotting of graphs, Mathematical and statistical analysis using software tools like MAT Lab, SPSS, PsiLAB other freeware tools, sigma plot, Origin.

Unit V:- Data analysis and fitting :- Probability, Laws of probability, Distribution functions and characterisitics Applicable probability distribution functions Binomial and Poisson distributions, laws of permutation and combinations, Gaussian distribution, central limits, chi squared and beta functions Monte-Carlo and random numbers Non-Uniform random deviates, Monte-Carlo integration and Markov chains Frequent statistics Data with uncorrelated and correlated error, Student's t-test, palcomponent analysis and Kolmogorov-Smirnov testing Linear and Non-linear fitting Least square fits, likelihood statistics, polynomial fits and fits with more than one pendentvariables Bayesian statistics Introductions, mean, median, mode, multi-parameter estimations, pothesis testing Fourier Analysis Basic treatment of fourier analysis, convolution and convolution orem Power spectra Introduction, continuous sequences, discrete sequences Analysis of equences, Convolutions, deconvolutions, data reconstruction, auto covariance and cross-covariance

References :-

1) Thesis & Assignment Writing–J Anderson, B.H.Dursten & M.Poole, Wiley Eastern, 1977
2) A Hand Book of Methodology of Research – P. Rajammal and P. Devadoss, R. M. M. Vidya Press, 1976.
3) The Craft of Scientific Writing by Michael Alley, (Springer).
4) Research Methodology by R. Panneerselvam, PHI, New Delhi 2005
5) Data Analysis for Scientists and Engineers by E. L. Robinson, 2016, ISBN9780-691-16992-7-2
6) Statistical and Computational Methods for Scientist and Engineers by S. Brandt, 2014, ISBN 9783-319-03762-2.

Compulsory course II (PHD-NANO-102) :- (4 credits)

Term review paper:- In this course, the candidates are expected to carry out literature research. The topic will shortlisted in consultation designated research guides from Nanoscience and Nanotechnology. The candidate is expected to do literature survey on the chosen topic and present short report of about 20-30 pages, having subsections such as

Introduction, national and international status and future scope. At the end of the course, the power-point presentation will evaluated by the committee constituted by NCNNUM Director.

Optional Course I (PHD-NANO-201):-

Synthesis of Nanoparticles by Chemical, Physical and Biological routes (2credits, 30 Hours (20 contact hours + (10 non-contact hours))

Colloids :- Introduction to Colloids and Colloids in Solutions, Effect of Charges on Colloids, Stearic Repulsion, Synthesis of Colloids, Nucleation and Growth of Nanoparticles

Chemical Methods :- Synthesis of Metal Nanoparticles by Colloidal Route, Synthesis of Semiconductor Nanoparticles by Colloidal Route, Langmuir-Blodgett (LB) Method , Microemulsions , Sol-Gel Method, Synthesis Using Micro-reactor or Lab-On-Chip

Physical Methods :- High Energy Ball Milling, Physical Vapour Deposition with Consolidation Ionized Cluster Beam Deposition, Laser Vapourization (Ablation) , Laser Pyrolysis Sputter Deposition, Chemical Vapour Deposition (CVD), Electric Arc Deposition Ion Beam Techniques (Ion Implantation), Molecular Beam Epitaxy (MBE)

Biological Methods:- Synthesis Using Microorganisms, Synthesis Using Plant Extracts Use of Proteins, Templates Like DNA, S-Layers,Synthesis of Nanoparticles Using DNA

Reference Books:-

1. Nanotechnology: Principles and Practices; Prof. S. K. Kulkarni, Springer Publication
2. The Chemistry of Nanomaterials: Synthesis, Properties and Applications; Prof. Dr. C. N. R Rao.. Wiley-VCH Verlag GmbH & Co. KGaA
3. Nanomaterials: Synthesis, Properties and Applications; A.S Edelstein and R.C Cammaratra
4. Nanostructures and Nanomaterials: Synthesis, Properties and Applications; Cao & Wang, World Scientific.

Optional Course II(PHD-NANO-202):-*

Magnetism in bulk and nanostructures:- (2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Magnetic moments of a body, alignment of atomic magnetic moments in a solid, Ferromagnetism, Curie Point and exchange integral, Magnetisation and magnetic domains, Temperature dependence of saturation magnetization, Coercive force and hysteresis,coercivity in nano particles. Ferrimagnetism and Antiferromagnetic order, Neutron magnetic scattering Magnetism of transition metals (elements, alloys and compounds),

Behavior of powders of ferromagnetic nanoparticles (Single/individual magnetic nanoparticles); Measurement of superparamagnetism and blocking temperature; Nanopore containment of magnetic particles; Antiferromagnetic nanoparticles; Rare-earths and Special Oxides (Spinels, Garnets and Perovskites). Magneto-resistance, tunnel magnetoresistance, Definitiohn of spintronics and examples of spintronic devices. Dilute magnetic semiconductors, Magnetic storage and spin valves.

Suggested Reading:-

1. Solid State Physics by Charles Kittle Wiely Publication
2. Introduction to magnetic materials By B.D. Cullity Addison-Wesley Publishing company
3. The physics and chemistry of nanosolids, FJ Owens and Charles P Poole Wiely publication

Optional Course III (PHD-NANO-203):-

Nanomaterials for energy applications:-(2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Energy harvesting photodevices, Solar Cells, various types of solar cells, and physics and chemistry of solar cells, nanomaterials in solar cells , Energy storage devices based on nanomaterials, Supercapacitors and batteries, Fuel cells, various types of fuels cells, hydrogen storage using nanomaterials. Energy nanocatalyst including photo-catalyst for water splitting, electro-catalyst. Nanoscale Energy Devices and Thermoelectrics.

Reference:-

1. Nano-energy: Nanotechnology Applied for Energy Production, Souza, Flavio L., Leite, Edson Roberto (Eds.) Springer.
2. Fuel Cells and Hydrogen Energy, Nanomaterials for solid state hydrogen storage, Robert Warin, Tomasz Czujko, Zbigniwe S. Wrongski, Springer.
3. Nanostructured Materials for Solar Energy Conversion by Tetsuo Soga, Elsevier.
4. Nanomaterials in energy devices by Hieng Kiat Jun, CRC press, Taylor and Francis Group.
5. Fuel Cell Systems Explained, James Larminie and Andrew Dicks, Willey international

Optional Course IV(PHD-NANO-204):-

Physics of Nano-electronic Devices (2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Quantum Mechanics for Nanoelectronic Devices :- fundamental Concepts of Quantum Mechanics, Solid State and Energy Bands, Energy Bands and Electrical Properties, Nanostructure Applications. Electron Transport and device physics: Semiconductors and carriers, career transport, generation, recombination and continuity, p-n junctions, metal semiconductor contacts and heterojunctions. MOS structure and CMOS devices: MOs structure, MOSFET and its operations, CMOS circuits. Quantum Well Devices: Issue in CMOS device scaling, Approach to overcoming scaling issue in nanoscale MOSFETs, Double gate MOSFETs, Tunneling and resonant tunneling devices. Quantum wire devices: Transport in one dimensional electron systems, Nanowire MOSFET. Quantum Dot devices: Zero Dimensional electron systems, modeling of single electron transistor. MOSFET as A molecular sensors: Basics of chemistry, and the importance of H+, EISFET, and Biomolecule based FET.

Reference:-

1. Nanoelectronic Devices, Byung-Gook Park, Sung Woo Hwang, Young June Park, Pan Stanford Textbook Series on Nanotechnology-Volume 1.
2. Lessons from Nanoelectronics: A New Perspective on Transport _ Basic Concepts (Lessons from Nanoscience: a Lecture Notes Series) by Supriyo Datta
3. Quantum Transport: Atom to Transistor by Supriyo Datta

Optional Course V(PHD-NANO-205):-

Introduction to Crystallography and X-ray Diffraction Analysis: (2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Concept of lattices 2 and 3D lattices, Bravis Lattice and Crystal structure, Lattice planes, lattice direction, Millar indices, diffraction of light on 1-D, 2-D and 3-D lattices, Laue condition of diffraction of X-ray on lattice points, Reciprocal lattice. X-ray powder diffraction analysis, Atomic scattering factor, structure factor. Systematic absence of X-ray lines in simple cubic, body Centered cubic and face center cubic structures. X-ray diffraction lines in rock-salt, cubic spinel, wurtzite structures.

Reference Books:-

(1) X-ray Methods : Analytical Chemistry by Open Learning , Whiston C. , John Wiley and Sons , 1987.

(2) Essentials of Crystallography, M.A. Wahab, Narosa Publication House, 2009.

(3) Crystal Structure Determination, Second edition, Werner Massa, Springer 2011.

Optional Course VI(PHD-NANO-206):-

(2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Electroanalytical techniques: -

Basics of electon transfer, Electrochemical cell, Thermodynsmics of charge transfer, Reference electrodes, Cyclic voltammetry, Randle Sevcic equation, Reversible, quasireversible , irreversible charge transfer. Chronoamperometry, Cottrell equation rotating ring electrodes, Levic equation kinetics of charge transfer, Butler volmmer equation, Voltammetry of nanoparticles.

Books :-

(1) Elecrochemical methods, second edition, Allen J. Bard and Lary Folkner, John Wiley and son, 2001.

(2) Electrode Potentials, Richard D. Compton, Oxford University Press, 1996

Optional Course VII(PHD-NANO-207):-

(2credits, 30 Hours (20 contact hours + (10 non-contact hours))

Micro/Nanofabrication:

Introduction (Nanotechnology, Nanofabrication); Micro/nano fabrication using optical Lithography techniques (Principle, Lithography at shorter wavelengths (deep UV, Extreme UV, X-ray)); Lithography at low k factor; Near field optical lithography; Maskless optical lithography; Micro/nano fabrication using charged beams (principle, focusing charged beam (sources, optics, aberrations)); Scattering and proximity effects; resists and materials; Nanofabrication using scanning probes; Nanofabrication by replication; Nanoscale pattern transfer (thin film deposition, pattern transfer by lift off, pattern transfer by plating, pattern transfer by stencil mask); subtractive pattern transfer (Isotropic wet etching; Anisotropic wet etching; reactive ion etching (RIE); RIE by inductively coupled plasma; ion milling); Nanofabrication by self- assembly (Introduction; self-assembly process, surface topography, electrostatic force, magnetic force), building blocks for future nano-systems (DNA scaffold; CNT, porous alumina)

Reference Books:-

(1) The Science and Engineering of Microelectronic Fabrication by S. A. Champbell: (Oxford Univ. Press, New York 2001).
(2) The MEMS Handbook by M. Gad-el-Hak (Ed.): (CRC, Boca Raton 2002).
(3) Nanotechnology principles and practices by S. K. Kulkarni: (Capital Publishing Company)
(4) Nanofabrication Handbook by G. Wiederrecht: (Elsevier)
(5) Micro and Nanofabrication technologies and applications by Z. Cui: (Springer)

Optional Course VIII Glasses and Glass Ceramics (2credits, 30 Hours (20 contact hours + (10 non-contact hours)

Introduction to glass & glass ceramics, Principles of glass formation, glass melting, Phase Separation, Structure of glasses, Viscosity of glass forming melts, Transport, mechanical and optical properties, Glass technology, Chemical analysis of glass, glass ceramics and related materials, biocomposites and bioceramics, Nano glass ceramics

Reference Books:-

1. P. McMillan - Basics of glass and glass ceramics
2. Shelby: Synthesis and Characterization of glasses and glass ceramics
3. D. Caurant: Glasses and glass ceramics for energy applications
4. Holland and Beall: Glass ceramic technology
5. Mineo Mizuno: Advances in Bioceramics and Biocomposites
6. Vahak Marghusian: Processing, Properties and applications, Nano Glass
7. Ceramics

PHD-NANO-301 (04 credits, working on Instruments, No formal contact hours) :-

This paper will be focused on Skill development, Hands on training of highly sophisticated instrument facility of the candidate: Minimum 03 major instruments in span of 03 semesters assigned by the director will be handled by the candidate for minimum 08 hours a week. The main idea of this paper is candidate will get opportunity to handle the sophisticated instrumentation facility at NCNNUM. His/her training will be transcended into carried our sample analysis assigned by the director. The course will help the candidate immensely in his/her present thesis work and future research career.The evaluation will be by the instrument in charge in consultation with Center Director, on the basis of skill acquired by the candidate and number of samples analysis carried out by them.