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| **Course Number** | : | ME627 |
| **Course Name** | : | Mesh Independent Computational Techniques |
| **Credits** | : | 3-0-0-3 |
| **Prerequisites** | : | FEM in Engineering (ME 513)/Advanced FEM (ME 601) |
| **Intended for** | : | M.Tech/MS/PhD/UG |
| **Distribution** | : | Elective course |

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## 1. Preamble:

In recent years, many mesh independent numerical methods have been developed to simulate problems with geometrical discontinuities or moving boundaries and highly oscillatory systems. Many challenging engineering problems such as solidification, microstructure modelling, material interfaces, bio-mechanics, fracture and fatigue, and asymptotic field problems can be solved much more easily with improved accuracy using the mesh independent methodology. This course describes the need and scope of mesh independent methods like meshfree methods and eXtended finite element method. The course emphasizes the preliminary introduction and mathematical formulations of various mesh independent computational techniques. It also attempts to include the implementation to specific engineering problems so that students can be benefited to pursue the research in the relevant area. This course focuses on various aspects with particular reference to application and implementation of methodology by using computer programming.

## 2. Course modules with quantitative lecture hours:

- **Scope and Need of Mesh Independent Methods   [9 hrs]**

  Equations for two-dimensional and three-dimensional solids, Strong-forms and weak-forms, Weighted residual method, Need of Mesh free methods, Solution procedure of MeshFree methods, Classification according to the formulation procedures, Classification according to the function approximation schemes.

- **Shape function construction [6 hrs]**

  Meshfree shape function construction, Point interpolation methods, Moving least squares shape functions, Interpolation error using Meshfree shape functions.

- **Methods based on global weak-forms [8 hrs]**

  Meshfree radial point interpolation method and formulation, Integration issues in RPI method, Imposition of essential BC in RPI method, Element Free Galerkin method formulation and shape function, Implementation issues and application examples in EFGM, Integration techniques and enforcement of BC in EFGM.

- **Methods based on local weak-forms [4 hrs]**

  Meshless Local Petrov-Galerkin method, Implementation issues and application examples.

- **eXtended Finite Element Method [6 hrs]**

  Difference between FEM and XFEM, Partition of Unity and Level set function, Intrinsic enrichment and Extrinsic enrichment, Numerical integration, Implementation and case studies.

- **Computer Implementation and Case Studies [9 hrs]**

FEM implementation with computer programming platform.

Implementation of meshfree EFGM using computer programming for analysis of (i) solid mechanics problem (ii) heat transfer problem. Enforcement of essential boundary condition will be implemented using Lagrange multiplier method.

Implementation of XFEM with extrinsic enrichment techniques for material discontinuity and crack discontinuity.

3. **Text books:**

- An Introduction to Meshfree Methods and their Programming, *G.R. LIU and Y.T. GU,* ISBN-13 978-1-4020-3468-8 Springer Dordrecht, Berlin, Heidelberg, New York. 2005.

- Extended Finite Element and Meshfree Methods, Timon Rabczuk, Jeong-Hoon Song, Xiaoying Zhuang, Cosmin Anitescu, ISBN: 9780128141069, Academic Press Elsevier, USA. 2019.

4. **References:**

- Meshfree Methods: Moving Beyond the Finite Element Method, *G.R. LIU,* ISBN 9781420082098 CRC Press Taylor and Francis Group, USA. 2018.

- Meshfree Methods for Partial Differential Equations, Lecture Notes in Computational Science and Engineering book series, Springer, Berlin, Heidelberg. 2017.

- Meshless Methods in Solid Mechanics, Youping Chen, James Lee, Azim Eskandarian, ISBN 978-0-387-30736-7, Springer, New York, USA. 2006.

- Meshless Methods and Their Numerical Properties, Hua Li, Shantanu S. Mulay, ISBN 9781138072312, CRC Press, Boca Raton, Florida, USA. 2013.

- Extended finite element method for Fracture Analysis of Structures, Soheil Mohammadi, ISBN: 978-1-4051-7060-4 Blackwell Publishing Inc., USA. 2008.

- Extended Finite Element Method: Theory and Applications, Amir R. Khoei, ISBN: 9781118457689, John Wiley & Sons. 2014.

5. **Similarity content declaration with existing courses:**

| Sl. No. | Course Code | Similarity Content | Approximate % of Content |
|---------|-------------|--------------------|--------------------------|
| 1 | ME352 | Strong-forms and weak-forms, Weighted residual methods | 5 % |

6. **Justification for new course proposal if cumulative similarity content is > 30%:** NA