**MEC-E8003 Beam, Plate and Shell Models; formulae**

**TENSORS**

, , etc.

 , 

 , 

  

   







**CURVILINEAR COORDINATES**



, ,

 , 

 (orthonormal coordinate system)

**CYLINDRICAL COORDINATES**



, , 



**SPHERICAL COORDINATES**



, , 

, 

**BEAM COORDINATES**



, ,



**SHELL COORDINATES**



, ,  ,

, 

**CYLINDRICAL SHELL COORDINATES**



, , 



**SPHERICAL SHELL COORDINATES**



, 

, , 

**CIRCULAR PLATE COORDINATES**



, , 









**LINEAR ELASTICITY**

, 

**Elastic material:** 

**Isotropic:** , 

**Plane stress:** , 

**Beam:**  , 

**Plate:** , ,

, , 

**PRINCIPLE OF VIRTUAL WORK**

(a function set)



**BEAM EQUATIONS**

,, , where 

, where 

**TIMOSHENKO BEAM** 

, , , 

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, 

**TIMOSHENKO BEAM** 

, ,, 

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**PLATE EQUATIONS**

, ,

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**REISSNER-MINDLIN PLATE** 





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, , 

**REISSNER-MINDLIN PLATE** 

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**KIRCHHOFF PLATE BENDING** 

, 

**MEMBRANE EQUATIONS IN CYLINDRICAL GEOMETRY** 

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**MEMBRANE EQUATIONS IN SPHERICAL GEOMETRY** 



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**SHELL EQUATIONS IN CYLINDRICAL GEOMETRY** 

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**SHELL EQUATIONS IN SPHERICAL GEOMETRY** 

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