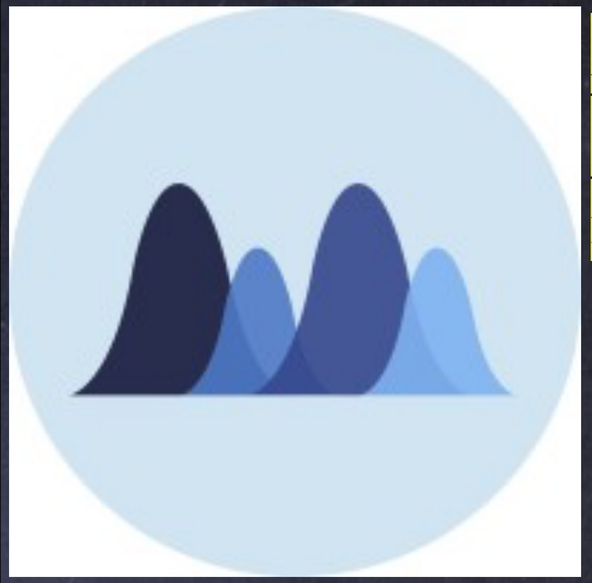
The Mechanics Discussions

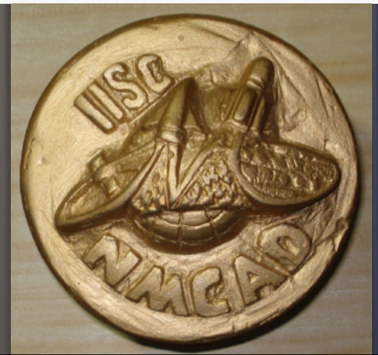


Aim: discuss best & cutting-edge developments in mechanics

INSPIRATIONS & EQUATIONS from VAM for MECHANICS of STUDENT LIFE!

Dineshkumar Harursampath

NMCAD Lab, AE, IISc



First half of talk title: INSPIRATIONS & EQUATIONS from V~~AM~~: Role of Variational Principles

- Inspirations from physics – physical – nature
- Equations from math – derived using:
  1. Newton's laws (vector: directed *dvaitic* approach) – differentiating – Law of ***karma***
  2. Variational principles (scalar: directionless *advaitic* approach) – integrating – Game of ***leela***
- Variational principles – components:
  1. Functional (Objective: Max. inner state of pleasantness: ***ānanda***)
  2. Constraints (environmental, physical & emotional obstacles: *prakriti, sthūla & sūkshma* ***vighna***)
  3. Dependent variables (way of life: *karma yoga + bhakti yoga + jñāna yoga + rāja yoga = sānkya* ***yoga***)
  4. Fields of operation (body + mind + intellect + energy = **robot**ic domain)
  5. Independent variables (space & time: ***kālā*** – measured thro' sensors to actuate dependent variables)
  6. Solution process (calculus of variations: identify *yoga* to max. *ānanda* thro' optimal conflict resolution)

CLASSICAL MECHANICS: ROLE OF VARIATIONAL PRINCIPLES

Size /Speed	<< c	O(c)
O(mm~km)	Macro-mechanics	Relativistic mechanics
O(μm)	Micro-mechanics	
O(nm)	Quantum mechanics	Quantum Field Theory

- Variational principles history: from **geometry for reflection** to **calculus for refraction** to **calculus of variation for mechanics**
  - 1st introduced for **refractive optics**: ✅ Fermat's **least duration** *vs* Leibnitz' **least impulse** ❌
    - **same solution** but Leibnitz thro' same **wrong assumption** as Descartes' vectorial approach (light travels faster in denser media!)
  - **Mechanics**: Bernoulli's **least duration** for ball's motion in frictionless groove under self-weight between 2 given points on vertical plane – solution: cycloid. By Euler's Guru, Johann, not Jacob et al., amongst 8 stars of Bernoulli family, @ *Vyās Peeth*!
  - ➡️ Lots to learn from 'other' fields & lots to teach 'others' too!
- Classical mechanics: Newtonian (no/simple field interactions) to Lagrangian to Hamiltonian (only way out for physically-sensible nonlinear, higher derivatives, kinematical constraints etc.)
  - Motion of macroscopic bodies: Deterministic present ➡ SOON stochastic future
  - ➡️ Present moment & environment **inevitable**, becoming ICs & BCs, respectively, but future **tailorable**
- System design:
  - parameters (dependent variables):
  - ability to respond as needed
  - ➡️ responsibility in student life

Second half of talk title: MECHANICS OF STUDENT LIFE:

Analogy of Composite Aircraft Structure & Student Life!

Parameter	Composite structure	Student life
Objective functional's integrand	[1]L = K - U	Kundalini Shakti = Life energy[2] – Death energy = Inner state of pleasantness
Constraints	[3]Support & loading conditions	Environmental, physical & emotional obstacles in life
Dependent variables	Displacement field or generalized co-ords, *q*	Path to take using actuators
Independent variables	Spatial & temporal: x_i, t	Space & time, sensed using sensors
Governing eqns.	Euler-Lagrange eqns.	Continually evolving with emotions, thoughts, words & deeds, based on choices/decisions made out of free will
BCs	[3]Support & loading conditions	Current generic transit chart at location of individual
ICs	Undeformed configuration (or plastic def.!)	Birth chart (*jathaka* or horoscope)

[2]**Leibnitz**: "KE living force, as opposed to pressure – dead force!"

For some motions, action is **min**., for others **max**; **Kraft's letter to Euler** (1753): "**Thrifty Mother Nature manages with least possible**, if she can do so; **but, if not, she pays honestly & as much as possible… not to be reputed miser!**" eg., **evolution** vs **tsunami/COVID-19** ➡️ **STATIONARY**

$$^{1}I = \int_{t_0}^{t_1} L(q, \dot{q}, t)\, dt.$$

$$L(q, \dot{q}, t) = K(q, \dot{q}, t) - U(q, t)$$

[3]**Mosolov: "One needs to feel the constraints!"**

MECHANICS – OVER THE AGES… IN THE WEST

- ~ 2,400 years ago – Aristotle, based on predecessors: "All manifestations of Nature follow **easiest** path that requires **least effort**." debunking current theory, "There isn't a substitute to **hard work**!" – True only for stupid donkeys, who don't love their work!!!
- ~ 2,300 years ago – Archimedes knew laws of **statics**
- 19 centuries gap before next step!!!
- ~ 400 years ago – Galileo, Descartes, **Fermat**, Newton, **Leibnitz**, Hooke, **Bernoulli**, et al.
- Galileo's 2 principles (basis of Newtonian mechanics; in spirit of Euclidian geom.): just mind games: expt. validation impossible!
  1. **Mechanics laws invariance** w.r.t. inertial frame change; FALLACY: inertial frame impossible!!!
  2. **Inertia principle**: non-interacting body's motion remains uniform indefinitely in unbounded space; FALLACY: isolated body impossible, leave alone unbounded space!!!
- ~300 years ago -- 1st variational principle in **mechanics**: **Mopertuis**: Min Action, $I = m*v*s$, followed by **Lagrange**, **Hamilton** et al.
- **Variational principle**: assertion that some quantity defined for all feasible/**admissible processes** reaches **stationary value for real process**, yielding governing eqns. for real process, possessing **spl. str.**
- ~ 40 years ago – VAM: **Berdichevsky**: "Most fundamental law of Nature revealed up to now: reciprocity of physical interactions: action of 1 field on another creates opposite & symmetric reaction." ➡️ Law of karma.
  - **All micro-physics** eqns. possess such str.
  - **Macro-physics** operates with averaged characteristics of micro-fields, leading to **thermodynamics** for eqb. processes.

Why "New" Models?

- insufficient accuracy/speed of "old" models
- need to change/shuffle across "old" models even for minor changes
- *ad hoc* (specific) & invalid assumptions in "old" models
- empirical nature of some "old" models
- nonclassical/nonlinear phenomena observed in reality not captured by "old" models
- low reliability of "old" models
- goal: illustrate potential of "new" models
  - sampling of worldwide advances in modeling techniques
  - illustration of detailed studies at Georgia Tech & NMCAD Lab, IISc

Emerging Techniques to Model Composite Structures

- **Vision**: Enable getting as close to truth as one intends with the least effort!
- **Mission**:
  - Better understand relevant non-classical phenomena ?
  - Simultaneously high-fidelity & high-efficiency mathematical models ?
  - Improved analysis & design techniques for current & futuristic applications
- **Strategy**:
  - Geometric & material nonlinearities as well as their evolutionary interaction
- **Enablers**: State-of-the-art mathematical approaches:
  1. Variational Asymptotic Method;
  2. Non-Deterministic Techniques;
  3. Concurrent Multi-scale Modeling; &
  4. Nonlinear Domain Decomposition.

How are composites modeled?

By making assumptions!

Are *all* assumptions necessary?

Are *all* assumptions relevant?

- Elastic material
- Material linearity
- No body-moment distribution
- Existence of S.E.D.
- Orthotropy
- Transverse isotropy
- Plane stress state
- Kirchoff-Love assumption: linear distribution of in-plane strains through laminate thickness
- Displacement field assumed
- Empirical correction factors