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Background

- Primarily engineering majors in calculus-based physics sections (~500/year)
- Quarter system with first (of four quarters) devoted to kinematics, mechanics (minus oscillation), and fluids
- Engineering faculty dissatisfied with level of instruction in statics

and, of course,

- Physics faculty dissatisfied with performance in general

DISCLAIMER

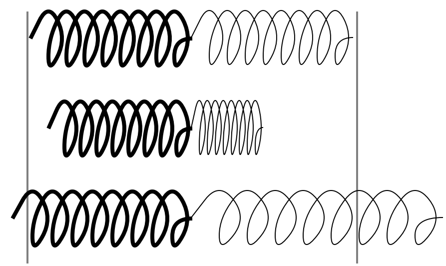
- The following represents immature and evolving thoughts

Observations

- *Instruction in kinematics (often or always) involves:*
  - > no physical principles
  - > a large set of complicated looking equations
  - > explicit teaching of bad problem solving habits
  - > time-dependent quantities requiring careful mental distinction and notation
  - > problematic evaluations of starting and ending “states”—e.g., “just after release” and “just before hitting the ground”
  - > a background of confusion about the velocity/acceleration distinction
- *Instruction in statics involves:*
  - > a simply-stated physical principle
  - > no time dependence
  - > the concept of a system
  - > free body diagrams / identification of forces
  - > straightforward vector math

Overview of Approach (first lessons)

- look at nature as a collection of interacting “systems”
- notice the overwhelming prevalence of “equilibrium”
- recognize equilibrium as the natural result of “dissipation” and self-regulating contact “forces”
- model the contact forces by the behavior of springs of varying stiffness (à la Clement)



- obtain a restricted case of Newton’s Third law
- define force (“arbitrarily”) in terms of a calibrated spring

Overview of Approach (first lessons) [cont'd]

- examine equilibrium situations and hypothesize
  $\vec{F}_{\mathrm{net}} = \Sigma\vec{F}_{on\ \mathrm{system}} = 0$ [vectors]

- identify and examine the *contactless* gravitational force

- introduce and define “gravitational mass” (arbitrarily in terms of relative *weights*) and “field” (in N/kg) to account for observations

- motivate and develop second condition
  $\vec{\tau}_{\mathrm{net}} = 0$ [cross product]

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Things to note (things I like!)

- Physics on day one, not week three or four
- A simple principle, not a set of complicated equations
  (stresses “how to apply the principle” rather than “how to find the right equation”)
- Early introduction to concepts of restoring force, oscillation, and dissipation which will be returned to later
- Vectors introduced in a non-displacement context
  (vector properties based on usefulness for describing observations rather than *apparent* physical necessity)
- “Gravitational field”, not “acceleration due to gravity”
- No time dependence; no early confusion re: velocity vs. acceleration and the dynamical effects of forces
- Early introduction to the physicist’s world view
  —i.e., “interacting systems”

Overview of Approach (later lessons)

Relative velocity

- note that all of the above takes place on a moving platform and infer that simple motion is unremarkable (Newton's First law)
- more vectors: $\vec{r}_{ba}$, $\vec{v}_{ba} \equiv \frac{d\vec{r}_{ba}}{dt}$, $\vec{v}_{ca} = \vec{v}_{cb} + \vec{v}_{ba}$

Overview of Approach (later lessons) [cont'd]

Momentum

- observe that $\vec{F}_{\text{net}} \neq 0$ causes change in “motion” and establish

  $$\Delta\vec{v} \;\alpha\; \frac{\vec{F}_{\text{net}}\ \Delta t}{m}$$

  [w/ minor digression on “equivalence”]

- remove arbitrariness from definition of the Newton

- manipulate the above to obtain $\Delta\vec{p} = \vec{J}$ and $\frac{d\vec{v}}{dt} = \frac{\vec{F}_{\text{net}}}{m}$ (Newton’s Second law)

- extend to multiparticle systems; *observe* conservation of momentum; infer Newton’s Third law

Overview of Approach (later lessons) [cont'd]

Angular momentum

- Minimal treatment intended primarily to complement the conservation of linear momentum

Energy

- Motivate $\vec{F}_{\text{net}} \quad \Delta\vec{r}$ as another measure of “effect”   [dot product]
- Work-Energy, conservation of energy

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Overview of Approach (later lessons) [cont'd]

Finally!!! Time "dependence"—$\vec{r}(t)$ and $\vec{v}(t)$

Uniform gravity/Constant force

- $\dfrac{d\vec{v}}{dt} = \dfrac{\vec{F}_{\text{net}}}{m} = \vec{g}$ (or at least constant) ["acceleration"]
- constant acceleration kinematics

Circular motion

Newtonian gravity and orbital motion

Oscillation

What gets left out

- rotational kinematics and rolling
- rotational dynamics (except for angular momentum and rotational kinetic energy)
- fluids (probably simply pushed to the next quarter)

What gets less emphasis

- friction
- Newton’s laws
- constant acceleration kinematics and dynamics
- center of mass and rotational inertia

What gets more emphasis

- static equilibrium
- conservation laws
- non-constant acceleration dynamics
- gravitational field
- oscillation

Reservations

- Approach is a little retro in some areas, especially beginning
- Is the concept of force too abstract to be made so central?
- Deemphasis of differential calculus skills that might be motivated and developed in early kinematics instruction
- Is it OK to deal with *changes* in velocity without worrying about *changing* velocity?
- Is it OK to eliminate rotational kinematics, rolling, $\vec{\tau}_{net} = I\vec{\alpha}$

and, of course,

- Will anybody else find the approach useful?
- Feedback?