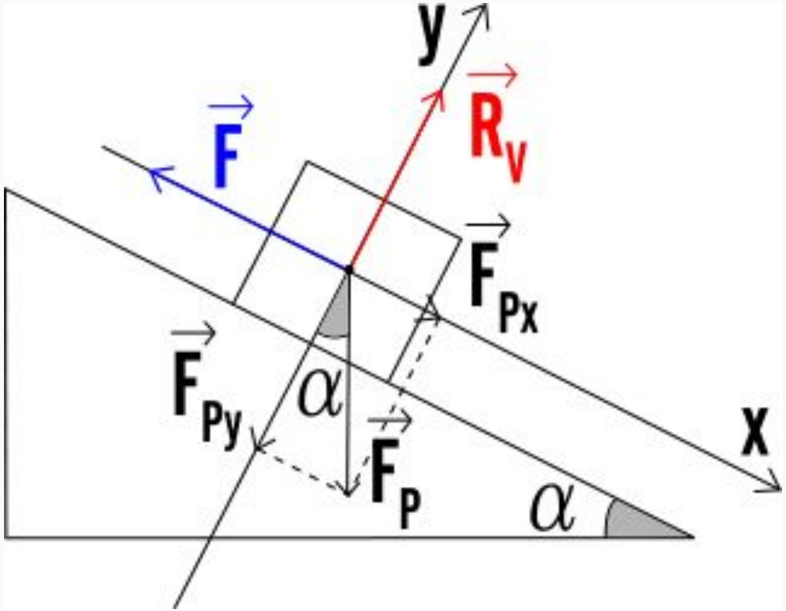
Physics Education Laboratory
Lecture 07
PCK for Dynamics

Francesco Longo - 26/10/20

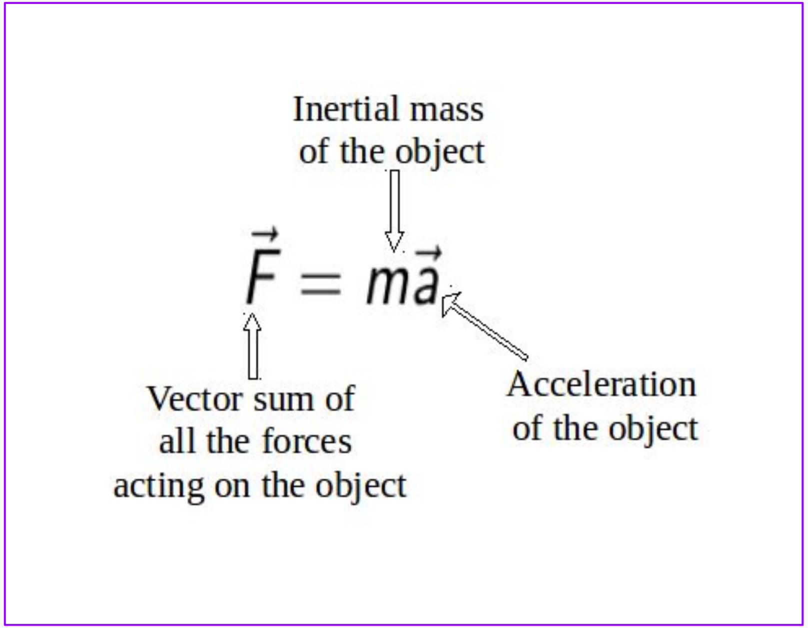
key concepts in Dynamics

- The three laws of Dynamics
- The concept of acceleration
- The concept of linear momentum
- The vector nature of the force
- The observer system
- The inertial system



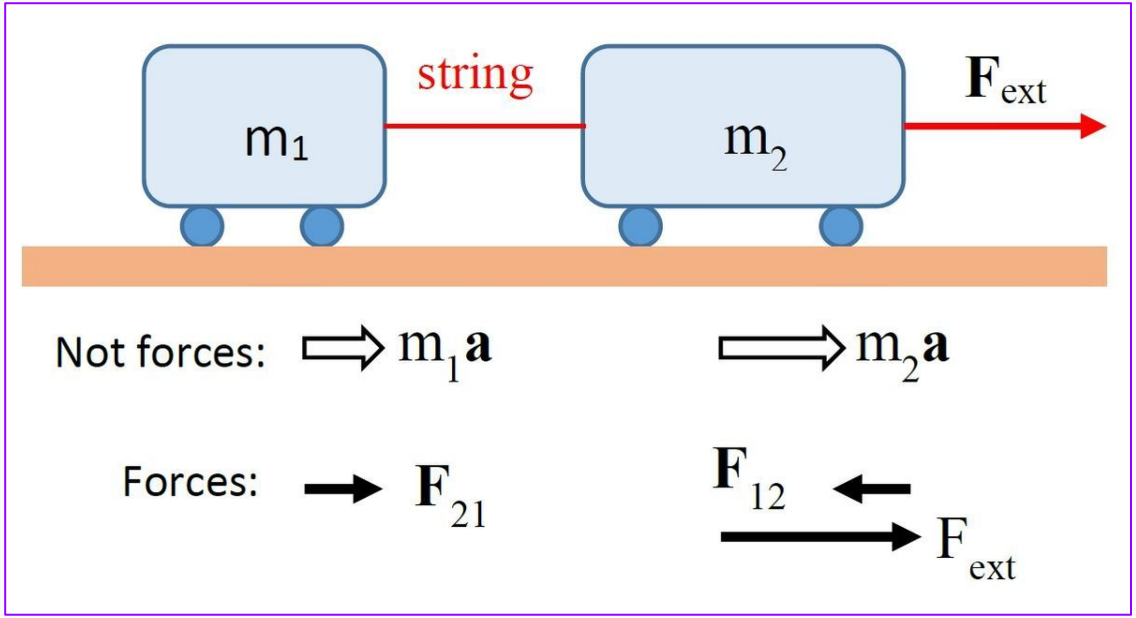
key concepts in Dynamics

- Newton’s second law



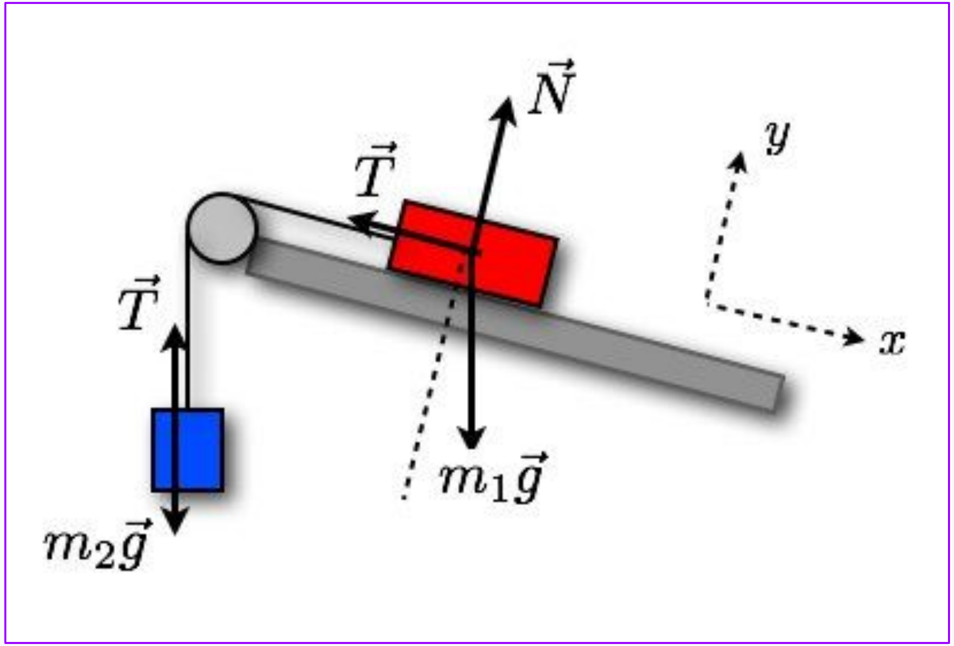
key concepts in Dynamics

- Newton's third law

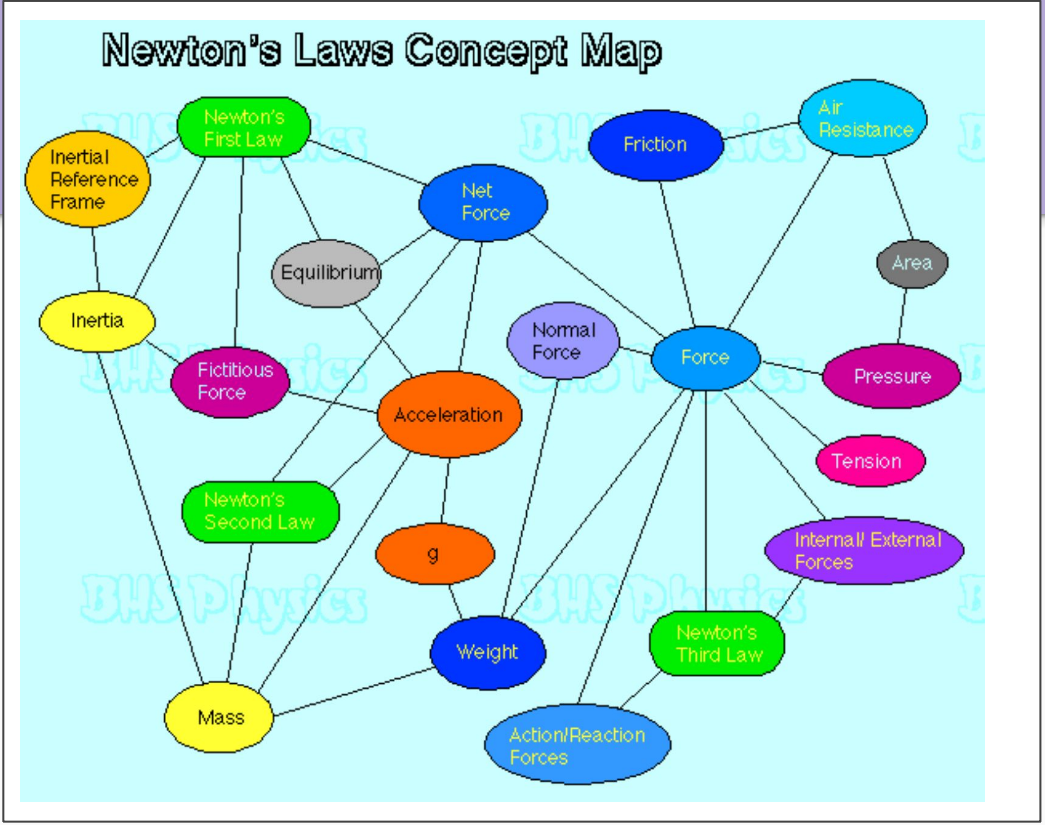


key concepts in Dynamics

- The Force …
- The free body approach



A concepts' map



http://www.batesville.k12.in.us/physics/PhyNet/Mechanics/Concept_Map.htm

From PCK

Knowledge of curricula

The knowledge of the sequence of topics that allows a student to build the understanding of a new concept or skill on what she or he already knows.

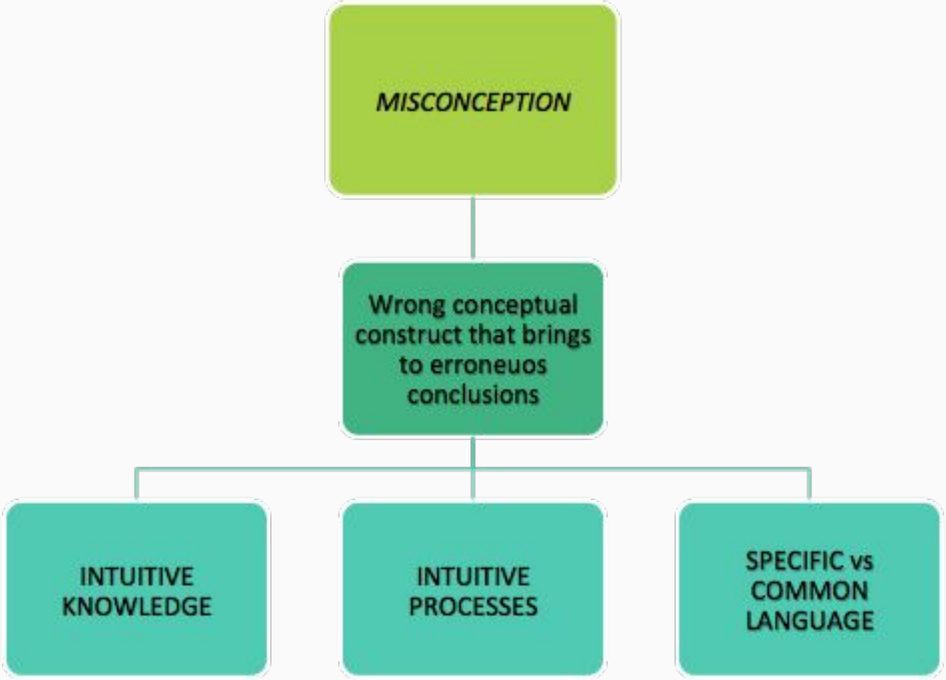
From PCK

Knowledge of students' prior understandings about and difficulties with key concepts and practices in science.

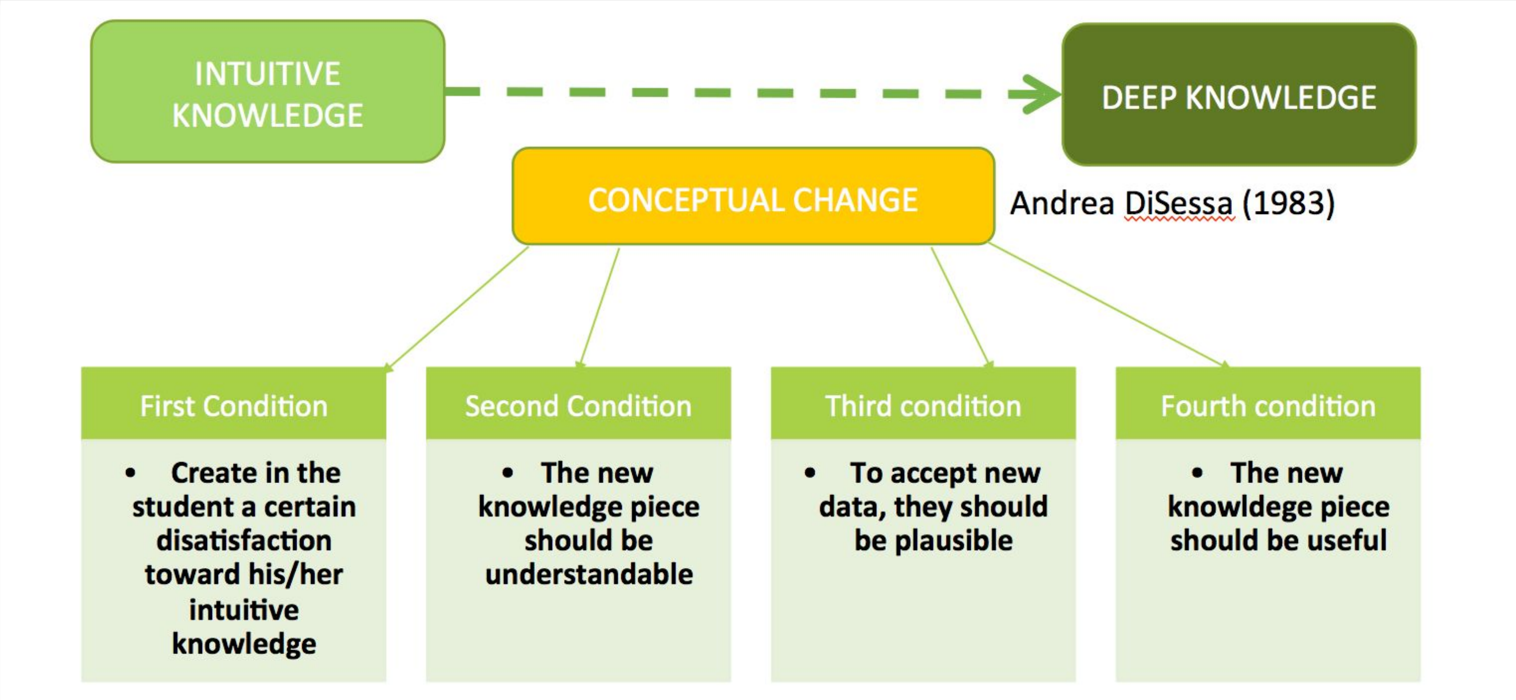
Knowledge of students' pre-instruction ideas when they are constructing a new concept.

Knowledge of difficulties students may have interpreting physics language that is different from everyday language.

Misconceptions (?)



The conceptual change



Intuitive Knowledge: Prior primitives (P-prims)

DiSessa, A. (1993). Toward an Epistemology of Physics.*Cognition and Instruction, 10*(2/3), 105-225. http://www.jstor.org/stable/3233725

P-prims are elements of intuitive knowledge that constitute people's "sense of mechanism," their sense of which happenings are obvious, which are plausible, which are implausible, and how one can explain or refute real or imagined possibilities.

- increased effort begets greater results;
- the world is full of competing influences for which the greater "gets its way," even if accidental or natural "balance" sometimes exists;
- the shape of a situation determines the shape of action within it (e.g., orbits around square planets are recognizably square in kids plots)

Ohm's p-prim

- *Schematization:* An agent or causal impetus acts through a resistance or interference to produce a result. It cues and justifies a set of proportionalities, such as "increased effort or intensity of impetus leads to more result"; "increased resistance leads to less result." These effects can compensate each other; for example, increased effort and increased resistance may leave the result unchanged.
- *Key attributes:* Resistance or interference, agency.
- *Prototypical circumstances:* Pushing a box with variable effort on different surfaces.
- *Relation to schooled physics:* Reused in Ohm's law. Glosses $\mathbf{F} = m\mathbf{a}$, with the force representing the causal impetus, m the resistance, and **a** the result.
- *Comments:* Central and very broadly applicable, from many physical to interpersonal relations such as influencing.

Force as mover

- *Schematization:* A directed impetus acts in a burst on an object. Result is displacement and/or speed in the same direction.
- *Attributes:* Violence.
- *Circumstances:* A throw.
- *Relation to schooled physics:* Glosses $\mathbf{F} = m\mathbf{a}$, but only from the state of rest. Responsible for "things go in the direction they are pushed" misconception.
- *Comments:* Involves Ohm's p-prim in reasoning about effect of impetus.

Force as deflector (cf. *force as a mover*)

- *Schematization:* A shove may act in concert with prior motion (momentum) to produce a compromise result, directionally between the two.
- *Relation to schooled physics:* May be a relatively low-priority p-prim "encouraged" by instruction because it is more compatible with $\mathbf{F} = m\mathbf{a}$.
- *Comment:* Frequently, subjects explicitly justified this, the evident deflection (after the fact), as a "compromise" in dynaturtle situations (diSessa, 1982). As many "combined effects" ideas, this seems to develop later and to have lower priority than categorical ideas ("the stronger influence gets its way").

Continuous force

- *Schematization:* As *force as mover*, but involving constant effort.
- *Attributes:* Steady effort.
- *Circumstances:* A car engine propels a car.
- *Relation to schooled physics:* May gloss $\mathbf{F} = m\mathbf{a}$. But when the result is taken to be speed (the early-on case) rather than acceleration (more sophisticated), it accounts for misconception of "motion requires a force."

Force as a spinner

- *Schematization:* Off-center pushes create spinning.
- *Circumstances:* Especially salient in cases of circular symmetry.
- *Relation to schooled physics:* Glosses torque laws but also undermine plausibility of linear $\mathbf{F} = m\mathbf{a}$ in such circumstances. Students think forces that create spin cannot simultaneously create linear motion or have a reduced effect in creating translation. This latter idea seems to involve a kind of principle of conservation of effect.

Intrinsic or spontaneous resistance (see *force as a mover*)

- *Schematization:* Especially heavy or large things resist motion.

Springiness (spring scale p-prim)

- *Schematization:* Objects give under stressing force. The amount of give is proportional to force.
- *Circumstance:* Clay or couch pillow under pressure.
- *Relation to schooled physics:* Becomes much more fundamental than rigidity, but it only glosses more detailed analyses.
- *Comments:* Initially, springiness is associated with semistatic phenomena and situations: little connection, for example, to oscillation, which would be a natural physicist association.

Equilibrium

- *Schematization:* A system with multiple influences has a natural domain of stability within some range of parameters of the influences.
- *Attributes:* Stability, nonaligned influences.
- *Circumstances:* An orbit may be viewed as stable confluence of centrifugal, gravitational, and other forces. Equilibrium is like balancing, as in dynamic balance, where conflict may not be salient.
- *Relation to schooled physics:* Must come to defer to mechanisms of stability that are much more specific and complex than simple equilibrium.
- *Comments:* This is a powerful, central p-prim that generalizes dynamic balance. There are frequently figural considerations.

Dynamic balance

- *Schematization:* A pair of forces or directed influences are in conflict and happen to balance each other.
- *Attributes:* Conflict, equality, steady state.
- *Circumstances:* Two people push against one another.
- *Relation to schooled physics:* Dynamic balance is generally compatible with physics instruction. It may be used to gloss "canceling forces."
- *Comment:* This phenomenon prepares for (cues) *overcoming*, should one of the forces involved increase or decrease.

p-prism on Dynamics (Di Sessa 1993)

- Ohm - p-prism
- Force as mover
- Force as deflector
- Continuous force
- Force as a spinner
- Intrinsic resistance
- Springiness
- Equilibrium
- Dynamic balance
- Overcoming

The Force Concept Inventory test

Revised form 081695R

Force Concept Inventory

Originally published in *The Physics Teacher*, March 1992

by

David Hestenes, Malcolm Wells, and Gregg Swackhamer

Revised August 1995

by

Ibrahim Halloun, Richard Hake, and Eugene Mosca

The Force Concept Inventory (FCI) is a multiple-choice "test" designed to assess student understanding of the *most basic* concepts in Newtonian mechanics. The FCI can be used for several purposes, but the most important one is to *evaluate the effectiveness of instruction*.

For a full understanding of what has gone into development of this instrument and how it can be used, the FCI papers (refs. 1, 2) should be consulted, as well as: (a) the papers on the FCI predecessor, the Mechanics Diagnostic Test (refs. 3, 4), (b) the paper on the Mechanics Baseline Test (ref. 5), which is recommended as an FCI companion test for assessing quantitative problem solving skills, and (c) Richard Hake's paper (ref. 6) on data collection on university and high school physics taught by many different teachers and methods across the U.S.A.

Refs. 1-5 are online at <http://modeling.asu.edu/R&E/Research.html> Ref. 6 is online as ref. 24 at <http://www.physics.indiana.edu/~hake>.

References

1. D. Hestenes, M. Wells, and G. Swackhamer (1992). Force Concept Inventory, *The Physics Teacher* **30**, 141-151.
2. D. Hestenes and I. Halloun (1995). Interpreting the Force Concept Inventory, *The Physics Teacher* **33**, 502-506.
3. I. Halloun and D. Hestenes (1985). The initial knowledge state of college physics students. *Am. J. Phys.* **53**, 1043-1055.
4. I. Halloun and D. Hestenes (1985). Common sense concepts about motion, *Am. J. Phys.* **53**, 1056-1065.
5. D. Hestenes and M. Wells (1992). A Mechanics Baseline Test, *The Physics Teacher* **30**, 159-166.
6. R. Hake (1998). Interactive-engagement vs. traditional methods: A six thousand-student survey of mechanics test data for introductory physics courses. *Am. J. Phys.* **66**, 64-74.

Active Laboratory on the FCI

https://forms.gle/oeyrKyYQoe3XV7y18