

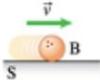
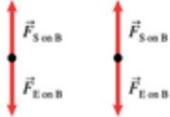
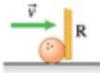
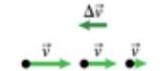
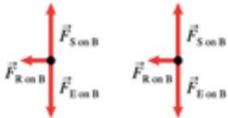
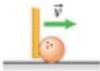
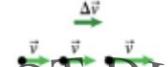
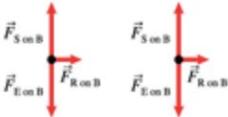
Physics Education Laboratory Lecture 07 Content Knowledge for teaching Dynamics

Francesco Longo - 13/10/25



Observational Experiment Table 3.1

How are motion and forces related?

Observational experiment	Analysis	
	Motion diagram	Force diagrams for first and third positions
<p>Experiment 1. A bowling ball B rolls on a very hard, smooth surface S without slowing down.</p> 	<p>$\Delta \vec{v} = 0$</p> 	
<p>Experiment 2. A ruler R lightly pushes the rolling bowling ball opposite the ball's direction of motion. The ball continues to move in the same direction, but slows down.</p> 	<p>$\Delta \vec{v}$</p> 	
<p>Experiment 3. A ruler R lightly pushes the rolling bowling ball in the direction of its motion. The ball speeds up.</p> 	<p>$\Delta \vec{v}$</p> 	

Pattern

- In all the experiments, the vertical forces add to zero and cancel each other. We consider only forces exerted on the ball in the horizontal direction.
- In the first experiment, the sum of the forces exerted on the ball is zero; the ball's velocity remains constant.
- In the second and third experiments, when the ruler pushes the ball, the velocity change arrow ($\Delta \vec{v}$) points in the same direction as the sum of the forces.

Summary: The $\Delta \vec{v}$ arrow in all experiments is in the same direction as the sum of the forces. Notice that there is no pattern relating the direction of the velocity \vec{v} to the direction of the sum of the forces. In Experiment 2, the velocity and the sum of the forces are in opposite directions, but in Experiment 3, they are in the same direction.

key concepts in Dynamics

- Newton's second law

The diagram shows the equation $\vec{F} = m\vec{a}$ centered on a white background. Three labels with arrows point to the terms in the equation: 'Inertial mass of the object' has a downward arrow pointing to the 'm'; 'Acceleration of the object' has a diagonal arrow pointing to the ' \vec{a} '; and 'Vector sum of all the forces acting on the object' has an upward arrow pointing to the ' \vec{F} '.

Inertial mass
of the object

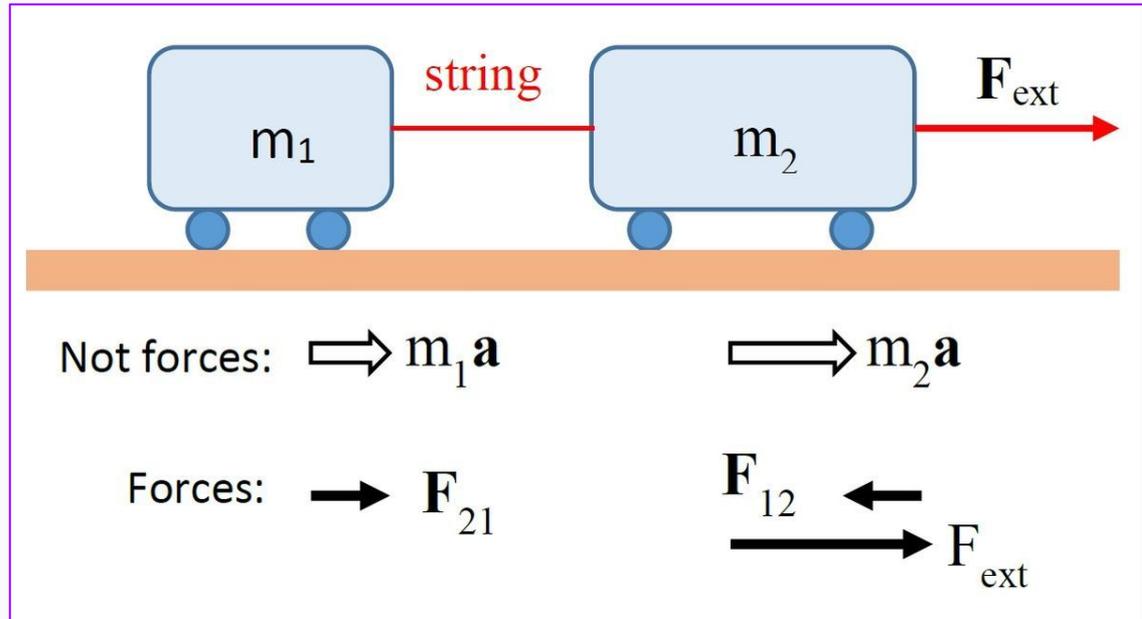
$$\vec{F} = m\vec{a}$$

Acceleration
of the object

Vector sum of
all the forces
acting on the object

key concepts in Dynamics

- Newton's third law



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

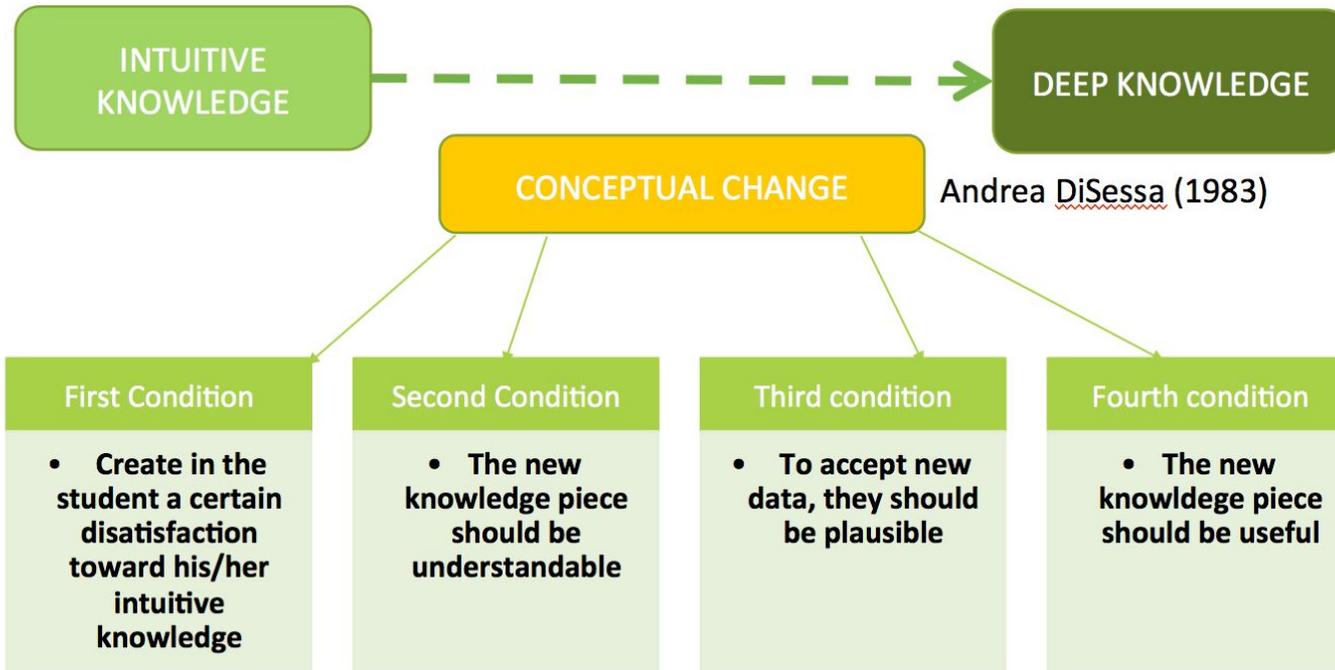
Knowledge of students' prior understandings about and difficulties with key concepts and practices in science.

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

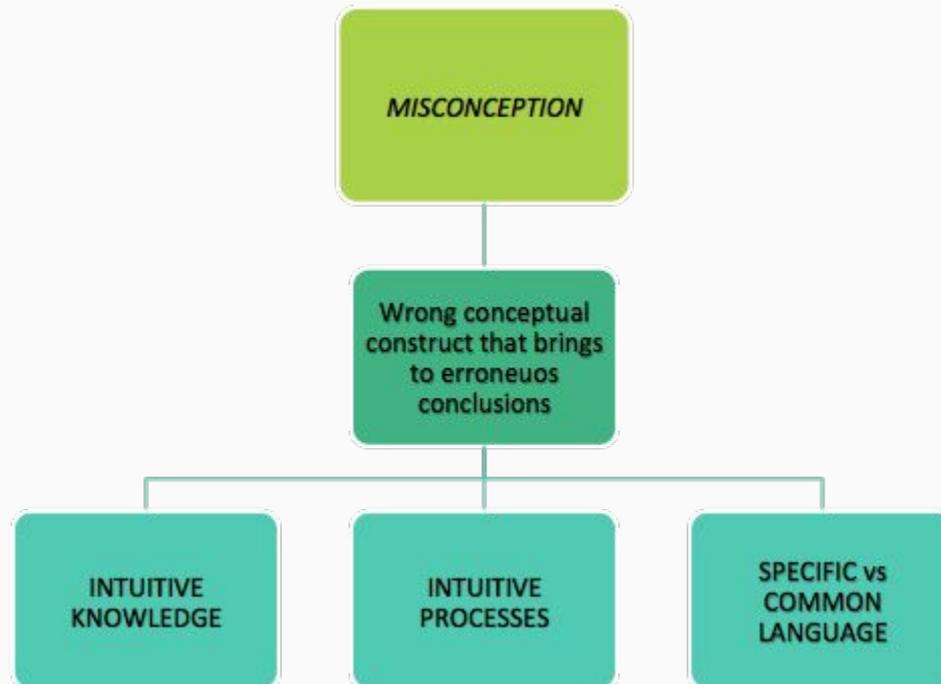
Knowledge of difficulties students may have interpreting physics language that is different from everyday language.

The conceptual change

The theory on conceptual change focuses on the process and outcome of how students' pre-instructional cognitive structures are fundamentally restructured in developing science concepts



Misconceptions (?)



In the conceptual change perspective, students' pre-instructional cognitive structures, which differ from expert conceptions, have commonly been referred as misconceptions

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 $F = ma$, 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 $F = ma$.
- *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 $F = ma$.* 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

The screenshot shows the PhysPort website interface. At the top, there is a dark blue header with the PhysPort logo (a red atom) and the text "PhysPort Supporting physics teaching with research-based resources". To the right of the header, there are links for "My Account | Logout", "About | Help | Contact", and the AAPT logo. A search bar with the placeholder text "Search PhysPort..." is also present.

Below the header is a navigation bar with five buttons: "Home", "Expert Recommendations", "Teaching", "Assessment" (highlighted in red), and "Workshops".

The main content area is titled "Assessments » Force Concept Inventory". It features a large blue wrench icon representing the FCI. To the right of the icon is a green "Download" button with a downward arrow.

The FCI description includes:

- Purpose:** To assess students' understanding of the most basic concepts in Newtonian physics using everyday language and common-sense distractors.
- Format:** Pre/post, Multiple-choice
- Duration:** 30 min
- Focus:** Mechanics Content knowledge (forces, kinematics)
- Level:** Intro college, High school

Below the description is a row of buttons: "Examples", "Resources" (with a globe icon), "Scoring", "Research" (with a star icon), "Translations", and "Versions".

On the right side, there is a "Variations" section with a green header. It lists two variations:

- Representational Variant of the Force Concept Inventory:** Content knowledge Mechanics (graphing, kinematics, forces, multiple representations). High school. Pre/post, Multiple-choice.
- Gender FCI:** Content knowledge Mechanics (kinematics, forces). Intro college, High school. Pre/post, Multiple-choice.

A vertical "Feedback" button is located on the far right edge of the page.

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

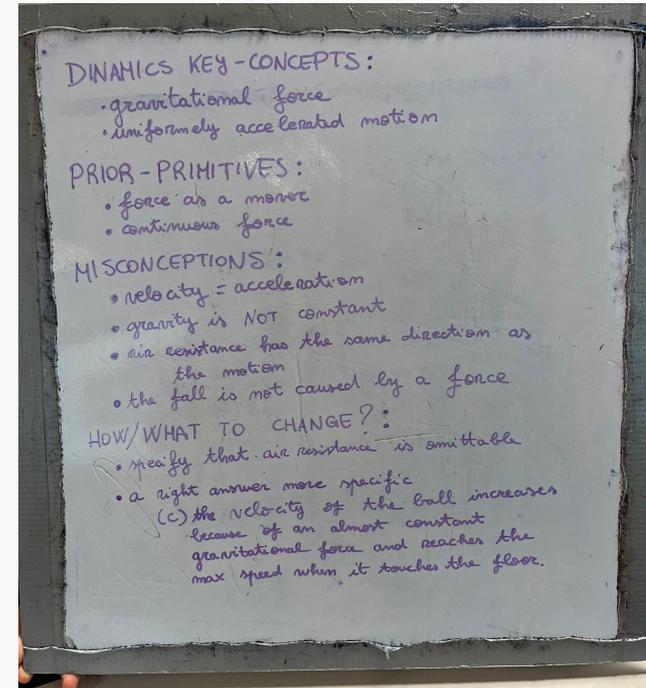
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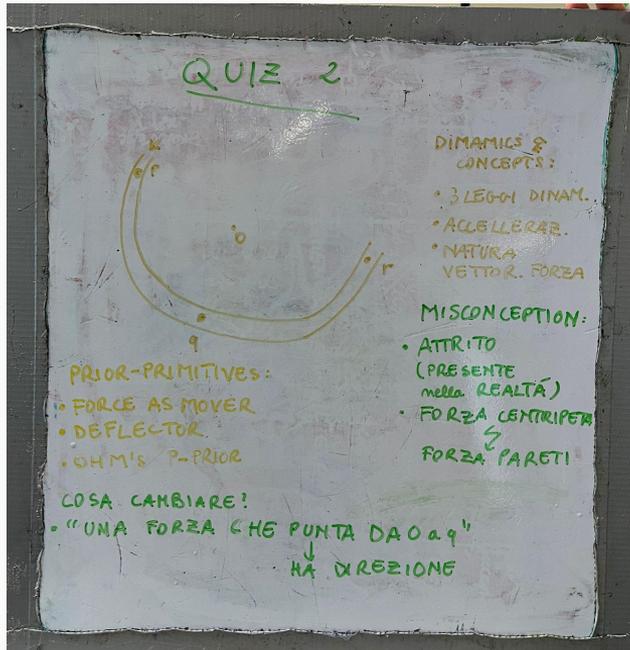
p-prism on Dynamics - FCI (2024)

QUESTION 1

3. Una pietra lasciata cadere dal tetto di un edificio di un solo piano:
- (A) raggiunge la massima velocità quasi subito dopo il rilascio e da quel momento in poi cade a velocità costante.
 - (B) la sua velocità cresce durante la caduta poiché l'attrazione gravitazionale diventa considerevolmente più intensa mano a mano che la pietra si avvicina alla Terra.
 - (C) la sua velocità cresce a causa di una forza di gravità quasi costante che agisce su di essa.
 - (D) cade a causa della tendenza naturale di tutti i corpi di fermarsi sulla superficie della Terra.
 - (E) cade a causa della combinazione degli effetti della forza di gravità che la spinge verso il basso e della forza dell'aria che la spinge verso il basso.

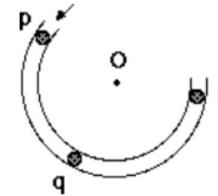


p-prism on Dynamics - FCI (2024)



QUESTION 2

La figura rappresenta un canale a forma circolare e privo di attriti centrato in O. Il canale è stato fissato sulla superficie orizzontale e priva di attriti di un tavolo. Stiamo guardando il tavolo dall'alto al basso. Le forze esercitate dall'aria sono trascurabili. Una palla è lanciata ad alta velocità nel canale nel punto p e ne esce nel punto r.



5. Considera le varie forze seguenti:

1. Una forza di gravità che punta verso il basso.
2. Una forza esercitata dal canale che da q punta verso O.
3. Una forza nella direzione del moto.
4. Una forza che punta da O a q.

Quale(quali) di queste forze agisce (agiscono) sulla palla quando essa si trova nel canale privo di attriti nel punto q?

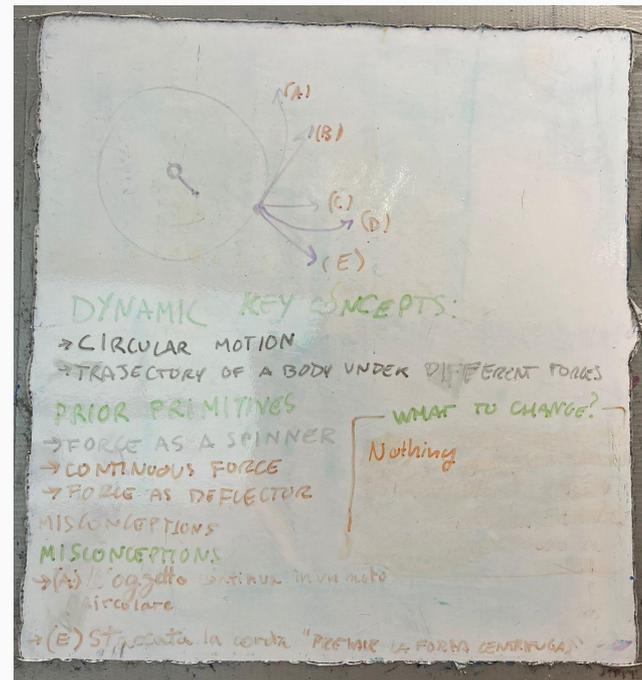
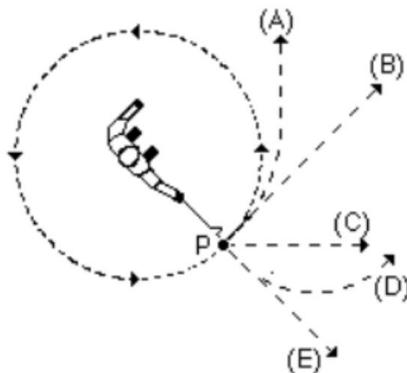
- (A) Solo la 1.
(B) La 1. e la 2.
(C) La 1. e la 3.
(D) La 1., la 2. e la 3.
(E) La 1., la 3. e la 4.

p-prism on Dynamics - FCI (2024)

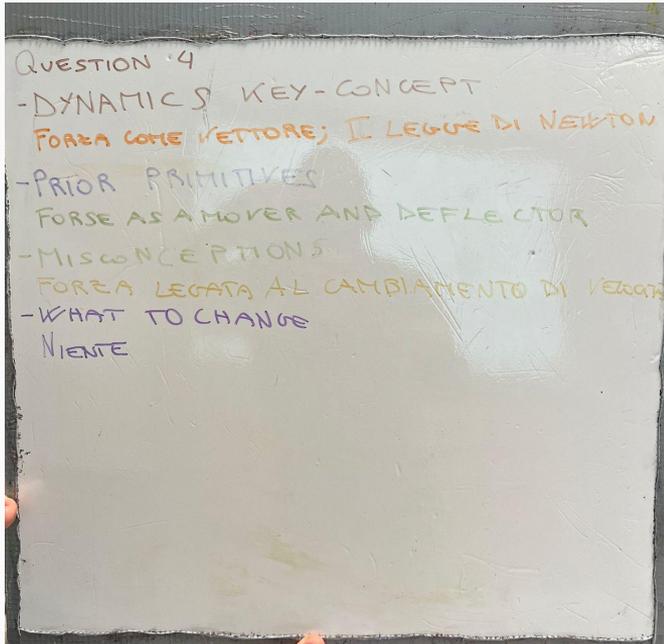
QUESTION 3

7. Una palla di acciaio è attaccata ad una corda che viene fatta ruotare secondo una traiettoria circolare, come illustrato in figura.

Nel punto P la corda improvvisamente si rompe in prossimità della palla. Se questo evento viene osservato direttamente dall'alto, come in figura, a quale traiettoria si avvicina di più il percorso seguito dalla palla dopo che la corda si è rotta?

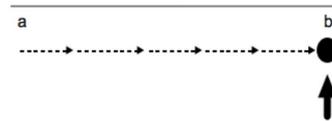


p-prism on Dynamics - FCI (2024)

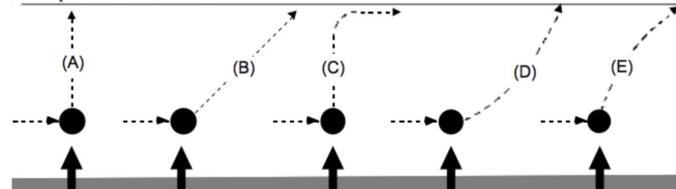


QUESTION 4

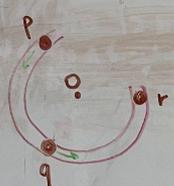
La figura mostra un dischetto da hockey che scivola su una superficie priva di attriti a velocità costante v_0 seguendo una linea retta dal punto "a" al punto "b". Le forze esercitate dall'aria sono trascurabili. Stai guardando il disco dall'alto. Quando esso raggiunge il punto "b" riceve un calcio orizzontale nella direzione indicata dalla freccia stampata in grande. Se il disco fosse stato a riposo nel punto "b", allora il calcio lo avrebbe messo in moto orizzontale con velocità v_x nella direzione del calcio.



8. A quale delle seguenti traiettorie si avvicina maggiormente il percorso seguito dal dischetto dopo aver ricevuto il calcio?



p-prism on Dynamics - FCI (2023)



1. Gravità verso il basso
2. forza da q ad O
3. v in direzione del moto
4. v da O a q

Quali agiscono sulla palla in q?

→ Dynamics key concepts "guarda il tavolo da sopra"
Dynamic laws, force, sdr osservatore

→ Prior-primitives traiettoria circolare
Continuous force, deflective force, intrinsic resistance attrito

→ Misconceptions moto continuo
Le forze da O a q o da q ad O sono "uguali"

→ What to change? ↳ hanno la stessa origine ??
↳ lo stesso sdr?

2. forza da q ad O (CENTRIFETA)
4. forza da O a q (CENTRIFUGA)



QUESTION 7

DYNAMICS KEY CONCEPTS:

Newton's third law

PRIOR-PRIMITIVES:

Continuous force, dynamic balance and force as mover

MISCONCEPTION → 

p-prism on Dynamics - FCI

QUESTION 3

Dynamics key concept
second law
Centripetal force
Inertia (first law)
Tension

Misconceptions

Seems clear

Prior primitives

Force as drifters
Continuous force

What to change?

Add circular path
(\rightarrow the object keeps
the previous trajectory)

QUESTION 4

DYNAMICS KEY-CONCEPTS

- the vector nature of the force $\rightarrow \vec{F}$
(- the observer system)

PRIOR - PRIMITIVES

- force as a mover
- force as a deflector

MISCONCEPTIONS

- Force continuous or instantaneous?

HOW / WHAT TO CHANGE

Nothing

Lesson Plan

- **PLAN an ACTIVITY ON KINEMATICS**
- **PLAN an ACTIVITY ON DYNAMICS**

- **Age**
- **Class composition**
- **When?**
- **What?**
- **How?**
- **Try ?**