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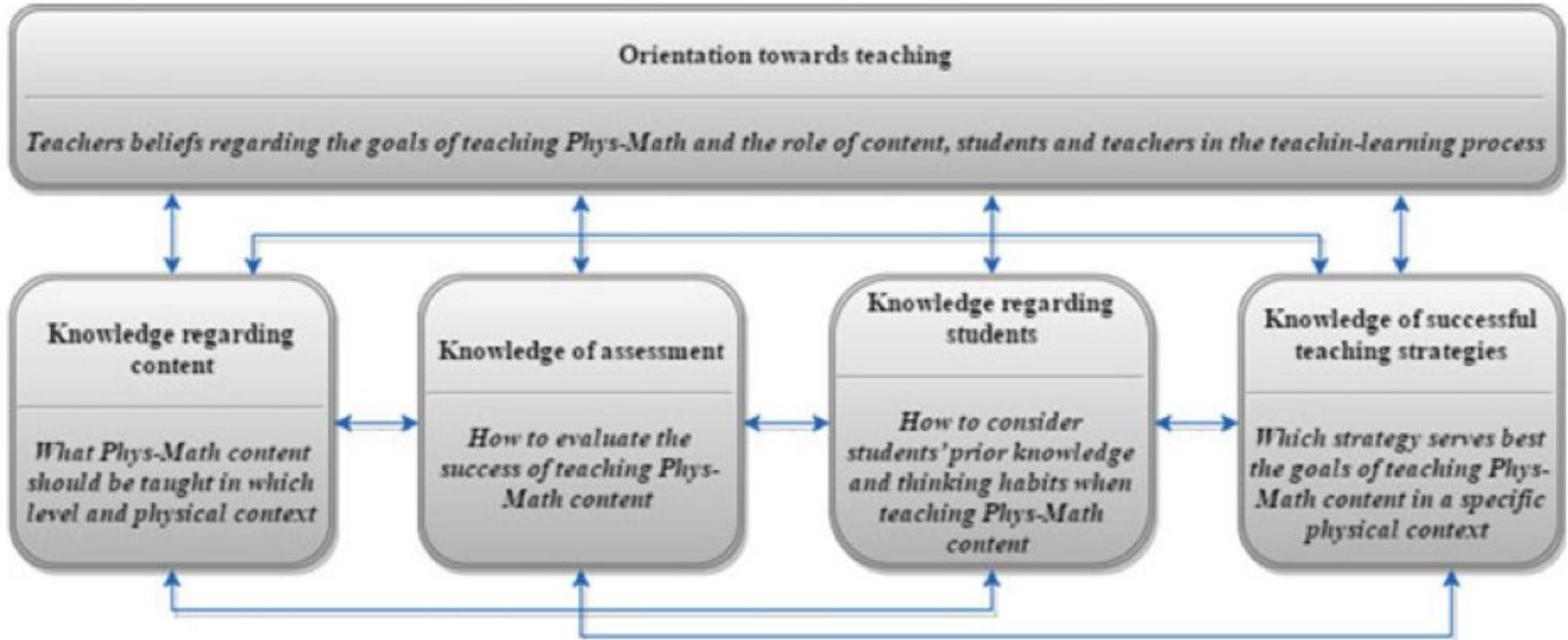
# Laboratorio Didattico di Fisica - Modulo A Lezione 04

Francesco Longo • 24/04/2025

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# Declining PCK for Math-Phys interplay

(Lehavi et al., 2014; 2017)



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# Keep in mind

1

## Exploration

Exploring within math ramifications for the physical system: borders (of validity, of approximation), extreme cases, etc.

2

## Construction

Constructing and developing (from experiments or from first principles) mathematical tools to describe and analyse physical phenomena

3

## Broadening

Adopting a bird's-eye view and employing general laws of physics, symmetries, similarities and analogies

4

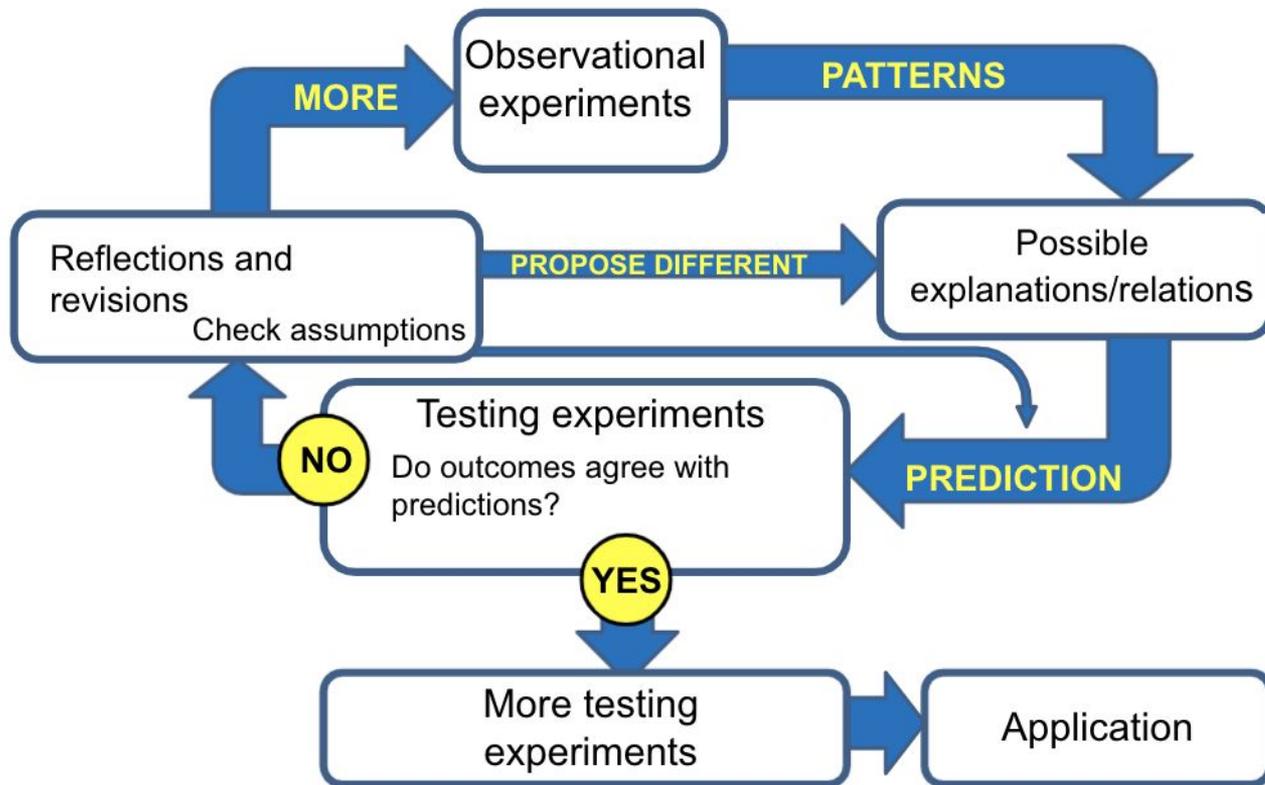
## Application

Employing already known laws and mathematical representations in problem solving

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# Investigative Science Learning Environment (ISLE approach)

## Investigative Science Learning Environment - ISLE cycle



# Rubrics for assessment

The Rutgers Physics and Astronomy Education (PAER) group has developed rubrics for assessment of scientific abilities. The rubrics contain descriptors for individual scientific sub-abilities. One can use the descriptors to assign either a numerical score or a descriptive score for a portion of student writing related to a certain sub-ability. The relationship between the scores is shown in the table below. We prefer to give students rubric description with a descriptive score as numerical scores were found to have a negative effect on student learning. A score of 0 describes a write-up in which the sub-ability is 'Missing', 1 stands for a write-up where the sub-ability is 'Not adequate', 2 describes a write-up with the sub-ability that 'Needs some improvement' and 3 describes a write-up in which is 'Adequate'.

- ❖ Ability to represent information in multiple ways
- ❖ Ability to design and conduct an observational experiment
- ❖ Ability to design & conduct an experiment to test an idea/hypothesis/explanation or mathematical relation
- ❖ Ability to design & conduct an application experiment
- ❖ Ability to communicate scientific ideas
- ❖ Ability to collect and analyze experimental data
- ❖ Ability to evaluate models, equations, solutions, and claims

# Esperimenti di osservazione: cosa sono?

***Esperimenti nei quali gli studenti investigano un fenomeno nuovo.***

Gli studenti non effettuano previsioni circa i risultati dell'esperimento, ma osservano e descrivono: raccolgono dati, li analizzano e trovano delle relazioni ricorrenti ("*patterns*") in essi.

Essi sono portati a elaborare una spiegazione per le relazioni trovate e/o a costruire una relazione qualitativa o quantitativa.

# Esperimenti di osservazione: perché usarli?

Gli studenti:

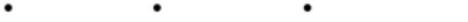
- riceveranno esperienze *concrete* come parte del ciclo di apprendimento
- imparano ad interpretare i dati senza sapere se sono giusti o sbagliati (*open-mind*)
- imparano a effettuare *scelte* su come rappresentare i dati e su quali relazioni cercare
- procedono in situazioni dove non c'è una risposta giusta o sbagliata, imparando modi produttivi per investigare fenomeni complessi (*cognizione epistemica*)
- imparano a trattare la complessità di *dati reali*

# Esperimenti di osservazione: come e dove usarli?

- a lezione: per sviluppare idee su un argomento nuovo. L'esperimento può essere svolto dal docente e gli studenti dovranno raccogliere ed elaborare i dati, decidere quali variabili sono importanti e trovare *patterns*. I dati o la loro analisi possono essere già forniti da terzi: in questo caso gli studenti dovranno solo trovare un pattern e fornire una spiegazione a riguardo;
- in laboratorio: dove gli studenti raccolgono ed elaborano i dati, trovano pattern e costruiscono spiegazioni o relazioni matematiche per descriverli;
- come compito per casa: si forniscono i dati agli studenti che dovranno analizzare e trovare patterns da soli.

# Observational Experiment Table 2.1

## Using dots to represent motion

Observational experiment	Analysis
<b>Experiment 1.</b> You push a bowling ball (the object of interest) and let it roll on a smooth linoleum floor. Each second, you place a beanbag beside the bowling ball. The beanbags are evenly spaced.	The dots in this diagram represent the positions of the beanbags you placed each second as the bowling ball slowly rolled on the floor. 
<b>Experiment 2.</b> You repeat Experiment 1, but you push the ball harder before you let it roll. The beanbags are farther apart but are still evenly spaced.	The dots in this diagram represent the positions of the beanbags, which are still evenly spaced but separated by a greater distance than the bags in Experiment 1. 
<b>Experiment 3.</b> You push the bowling ball and let it roll on a carpeted floor instead of a linoleum floor. The distance between the beanbags decreases as the ball rolls.	The dots in this diagram represent the decreasing distance between the beanbags as the ball rolls on the carpet. 
<b>Experiment 4.</b> You roll the ball on the linoleum floor and gently and continually push on it with a board. The distance between the beanbags increases as the pushed ball rolls.	The dots in this diagram represent the increasing distance between the beanbags as the ball is continually pushed across the linoleum floor. 
<b>Pattern</b>	
<ul style="list-style-type: none"><li>• The spacing of the dots allows us to visualize the motion of the object of interest.</li><li>• When the object travels without speeding up or slowing down, the dots are evenly spaced.</li><li>• When the object slows down, the dots get closer together.</li><li>• When the object moves faster and faster, the dots get farther apart.</li></ul>	

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?



# Esperimenti di test: cosa sono?

*Esperimenti nei quali gli studenti usano una spiegazione o una relazione per effettuare previsioni circa il risultato di un esperimento.*

Gli studenti eseguono l'esperimento e registrano il risultato. Basandosi sull'accordo (o meno) della previsione con i risultati sperimentali, e tenendo conto delle assunzioni teoriche, dei modelli usati e delle incertezze sperimentali, essi devono effettuare giudizi circa la spiegazione o le relazioni che stanno testando.

Essi dunque imparano che se la loro previsione è d'accordo con l'esperimento, la spiegazione o la relazione pensata non può essere rifiutata, mentre se non c'è accordo essi devono rigettare la spiegazione o riconsiderare le loro assunzioni.

# Esperimenti di test: perché usarli?

Gli studenti:

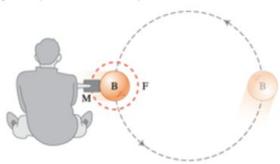
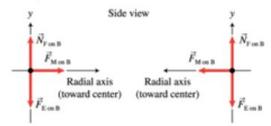
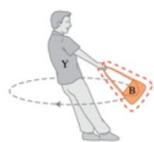
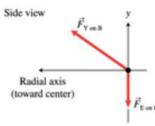
- imparano il ragionamento *ipotetico-deduttivo* (logica del “se”, “e”, “ma” “allora”...)
- imparano a basare la loro conoscenza sull’evidenza e non sull’autorità
- imparano la differenza tra assunzione, previsione, spiegazione
- imparano che la discordanza tra previsioni e esperimento può essere dovuto a svariati fattori: assunzioni incomplete, spiegazioni errate, o tecniche sperimentali inadeguate
- imparano a scegliere quando rigettare una spiegazione per un fenomeno

# Esperimenti di test: come e dove usarli?

- a lezione: il docente descrive l'apparato sperimentale e gli studenti effettuano previsioni dell'esperimento a seguito di una spiegazione precedentemente elaborata. Il docente (o un terzo) esegue l'esperimento e gli studenti decidono l'accordo o meno delle previsioni con i risultati dell'esperimento
- in laboratorio: gli studenti eseguono in prima persona l'esperimento dopo aver effettuato delle previsioni, e giudicano in seguito l'accordo o meno con i risultati dell'esperimento. L'esperimento può anche essere ideato dagli studenti in prima persona, a seconda del materiale a disposizione.

# Observational Experiment Table 5.1

## Forces exerted on an object moving in a circle at constant speed

Observational experiment	Analysis
<p><b>Experiment 1.</b> A bowling ball is rolled toward you over a smooth floor. You are asked to tap it with a mallet to make the ball roll in a circle with constant speed. You find that directing the mallet taps along the desired circular path doesn't work; the ball rolls wide. The only thing that works is to tap <i>directly toward the center of the desired circle</i>.</p> 	<p>There are three objects interacting with the bowling ball: Earth, the floor, and the mallet. We assume that the force exerted by the floor is perpendicular to the floor's surface. The force diagrams for the ball at two locations are shown below. We see that at each location the sum of the forces points toward the center of the circle.</p> 
<p><b>Experiment 2.</b> You hold a bag by the handle and swing it in a horizontal circle at constant speed. You observe that your arms pulling the bag are angled down with respect to the horizontal.</p> 	<p>Two forces are exerted on the bag as it moves around the circle: Earth pulls downward, and you pull at an angle with the vertical. The vertical component of the force that you exert on the bag must balance the force that Earth exerts on it because the bag does not accelerate in the vertical direction. Consequently, the sum of these two forces again points toward the center of the circle.</p> 
<p><b>Pattern</b></p> <p>In each case, as shown in the force diagrams, the sum of the forces exerted on the circling object points directly toward the center of the circle.</p>	

Watch *Circular motion*

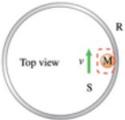
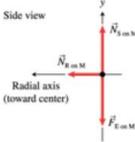
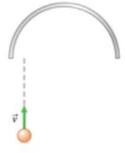
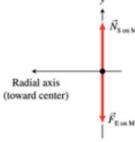
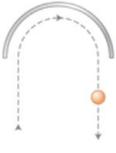
# FIND A PATTERN

Experiment; the circling object is in bold.	List objects that interact with the circling object.	Draw a top view force diagram for the circling object.	List forces or force components that add to zero.	Indicate the direction of the sum of the forces exerted on the object.
a. Tapping a <b>bowling ball</b> . So it moves in a circle on the floor				
b. Swinging a <b>bucket</b> in a horizontal circle.				
c. Pulling a rope attached to a moving <b>rollerblader</b> so she moves in a circle.				



## Testing Experiment Table 5.2

Does the sum of the forces exerted on an object moving at constant speed in a circle point toward the center of the circle?

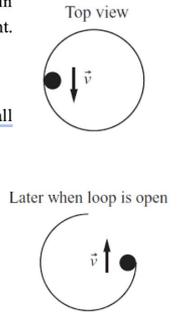
Testing experiment	Prediction	Outcome
<p><b>Experiment 1.</b> You roll a marble against the inside wall of a metal ring sitting on a smooth surface.</p> 	<p>The force diagram for the marble is shown below.</p>  <p>The vertical force components add to zero. The sum of the forces points along the radial axis toward the center of the circle. Thus we predict that the marble will roll along the wall of the ring following the circle.</p>	<p>As you can see in the video, this is exactly what happens. The marble rolls inside the ring following the circle.</p> 
<p><b>Experiment 2.</b> You roll a marble at constant speed toward a semicircular metal ring sitting on a smooth surface.</p> 	<p>When the marble rolls toward the ring, the sum of the forces exerted on it is zero, so we predict that it will move in a straight line with constant velocity. When it reaches the ring, the sum of the forces will point toward the center of the ring, so we predict it will follow the ring as in Experiment 1. Once the marble reaches the end of the ring, it should continue in a straight line as before.</p> 	<p>The video of the experiment shows that our prediction matches the outcome.</p> 
<p><b>Conclusion</b></p> <p>The outcomes of both experiments are consistent with the pattern of the sum of the forces exerted on an object moving at constant speed in a circle pointing toward the center.</p>		

For the following testing experiment, use the pattern that you formulated in Activity 5.1.2 and Newton's laws to predict the outcome of the experiment. Do not watch the video until you finish part **b** of this activity.

**a.** Inside a metal ring, a person rolls a small ball or a marble on a smooth horizontal surface. The marble rolls along the ring. Is the motion of the ball consistent with the pattern formulated in Activity 5.1.2? Explain.

**b.** Use the pattern you found in Activity 5.1.2 (not your intuition) to predict what will happen to the ball if, after the ball rolls for a couple of turns, the person removes a quarter of the ring as shown in the figure. Justify your prediction in words and with a force diagram before you watch the video of the experiment.

**c.** After you make your prediction, watch the video, and compare the outcome to your prediction. What judgment can you make about the idea that you're testing? Does the outcome support, prove, or disprove the idea you're testing?



# Esperimenti di applicazione: cosa sono?

*Esperimenti che includono il risolvere un problema pratico o determinare una quantità sconosciuta mediante un esperimento.*

Agli studenti può venire chiesto di usare più metodi sperimentali per determinare una stessa quantità e confrontare i risultati.

# Esperimenti di applicazione: perché usarli?

Gli studenti:

- imparano ad affrontare problemi realistici
- imparano ad affrontare un problema da più punti di vista, usando più idee e confrontandole
- imparano a scegliere quali assunzioni effettuare per risolvere un problema e cosa tralasciare
- imparano ad applicare la fisica nella vita di tutti i giorni usando strumentazioni semplici
- imparano a confrontare risultati di diversi esperimenti

# Esperimenti di applicazione: come e dove usarli?

- in laboratorio: agli studenti è richiesto di calcolare una quantità fisica effettuando un esperimento con degli strumenti a loro disposizione
- come problema-video: gli studenti possono raccogliere dati guardando un video di un esperimento e risolvere il problema richiesto (si può fare anche in classe o come compito per casa)

# Types of quantitative reasoning activities.

Type of activity	Short description
<i>Contextually interesting problems</i>	Relatively standard problems which have interesting contexts
<i>Multiple representation problems</i>	Students represent a word problem in different ways (such as, a sketch, graph, diagram, and equation)
<i>Equation Jeopardy problems</i>	Students are given an equation and are asked to construct other representations of a physical process that are consistent with the equation.
<i>Problem-posing problems</i>	A physical situation is described in one way and students are to invent a problem involving the situation.
<i>Evaluation problems</i>	Students are provided a solution for a problem and are asked to evaluate it for errors or in other ways.
<i>Design and analyze problems</i>	More complex problems where students need to design an experiment to achieve some goal and to development an appropriate mathematical solution to answer the question. The problems often involve concepts from different conceptual areas (for example, energy and circular motion).

# Problem solving strategy.

General steps of the problem solving strategy	Modifications of the steps for the circular motion chapter
<i>Picture and translate</i>	Sketch the situation described in the problem statement. Choose a system when the object is at one particular position along its circular path. Draw an axis in the radial direction toward the center of the circle.
<i>Simplify</i>	Decide if you can consider the system as a particle Determine if you can ignore any interactions of objects outside the system with the system object. Determine if the constant speed approach is appropriate.
<i>Represent physically</i>	Indicate with an arrow the direction of the acceleration when passing the previously determined position Draw a free-body diagram for the object at the instant it passes that position.
<i>Represent mathematically</i>	Convert the free-body diagram into the radial component form of Newton's second law. For objects moving in the horizontal plane, you may also need to apply the vertical component form of Newton's second law to solve the problem
<i>Solve and evaluate</i>	Solve the equations formulated in the previous two steps and evaluate the results to see if they are reasonable (the magnitude of the answer, its units, how the solution changes in limiting cases, and so forth.

Example of ISLE at work ..

[https://docs.google.com/document/d/1F7XA\\_jZz8bIhB4RxS6cWgDJn4DbUQkn0/edit](https://docs.google.com/document/d/1F7XA_jZz8bIhB4RxS6cWgDJn4DbUQkn0/edit)

[https://drive.google.com/file/d/1YOWDDJujMnD\\_BY5gw60eDNtxqjeiPXjN/view?usp=sharing](https://drive.google.com/file/d/1YOWDDJujMnD_BY5gw60eDNtxqjeiPXjN/view?usp=sharing)

Example 1:

First law of thermodynamics

- Sistema in equilibrio - Statica (del punto e del corpo rigido)
- Moto uniformemente accelerato
- Moti in 2D
- Moto rotatorio
- Circuiti in serie e in parallelo
- Galleggiamento
- Bernoulli

# STATICA del CORPO RIGIDO



# MOTO UNIFORMEMENTE ACCELERATO



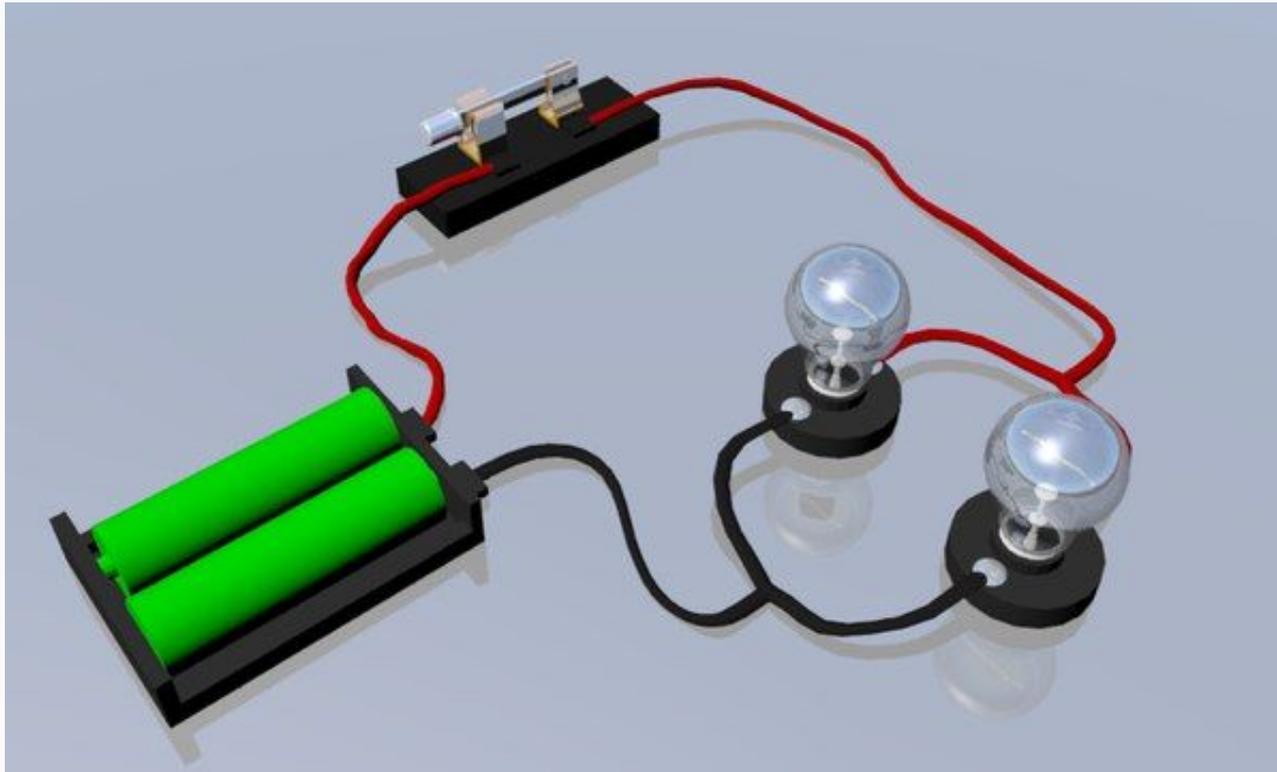
# MOTI IN 2D



# MOTO ROTATORIO



## CIRCUITI IN SERIE - PARALLELO



# GALLEGGIAMENTO



BERNOULLI



Individuare:

Esperimento Osservativo  
Esperimento di Test



[https://media.pearsoncmg.com/aw/aw\\_etkina\\_cp\\_2/videos/content/oalg\\_users.php](https://media.pearsoncmg.com/aw/aw_etkina_cp_2/videos/content/oalg_users.php)

## Aiuto a casa...:

- Statica: Chapt. 8
- Moto accelerato: Chapt. 2
- Moto 2D: Chapt. 4
- Moto circolare: Chapt. 5
- Circuiti: Chapt. 19
- Galleggiamento: Chapt. 13
- Bernoulli: Chapt. 14

- Circuiti:
- Esperimento Osservativo - PHET Circuiti (serie, parallelo, corrente nei vari punti, voltaggio)
- Resistenze nei due casi, Corrente nei Circuiti Parallelo e Serie, Tensione relazione nei due casi.
- Esperimento Test -  $V = RI$

- Circuiti:
- Serie vs Parallelo - Video sul circuito in parallelo - 4 lampadine (Serie/Parallelo non noti) – da provare (quali si spengono)
- Test Luci Natale: Serie / Parallelo

- Galleggiamento:
- Esperimento Osservativo: pesi diversi in acqua. - Bacinella Graduato

Equazione Continuità:

Esperimento Osservativo: Tubo otturato +/- distante

Pattern: ne esce + o -

Esperimento Test: Misura di tempo di riempimento