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Strengthening Teaching Competences
in Higher Education
~~in Natural and Mathematical~~
Sciences

Implementation of *Peer Instruction* into the lectures

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Training Fan S. Noli University, Korçë, Albania,
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Implementation of *Peer Instruction* into the lectures

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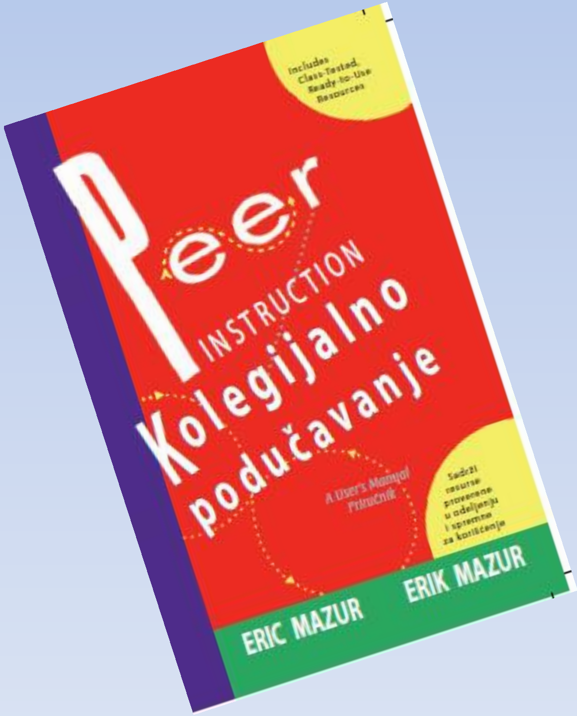


Peer Instruction – A User's Manuel by Erik Mazur (translation into Serbian language)

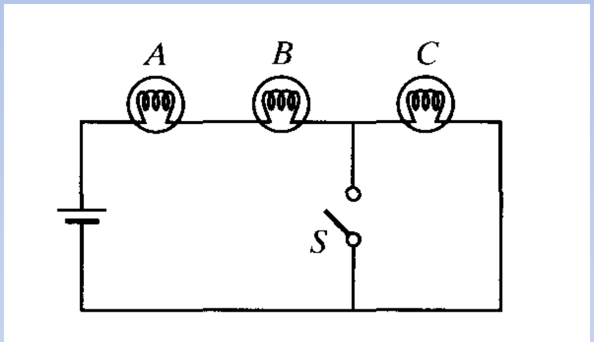
Prof. Erik Mazur

The Key References

- Halloun, I. and Hestenes, D. (1985), The initial knowledge state of college Physics students, Am. J. Phys., 53(11), 1043-1055.
- Halloun, I. and Hestenes, D. (1985), Common Sense Concepts about Motion, Am. J. Phys., 53(11), 1056-1065.
- Hestenes, D., Wells, M. and Swackhamer, G. (1992), Force Concept Inventory, Phys. Teach., 33(3), 141-151.
- Mazur, E. Peer Instruction: A User’s Manual, New Jersey: Prentice Hall, Inc., (1997); Мазур, Е. Колегијално подучавање: приручник, превели Поповић-Божић, М., Жекић, А. Београд: Физички факултет, 2016.

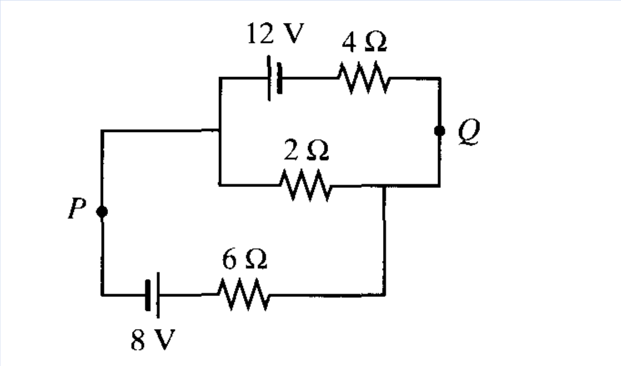
Memorization vs understanding

1. A series circuit consists of three identical light bulbs connected to a battery as shown here. When the switch *S* is closed, do the following increase, decrease, or stay the same?



(*a*) The intensities of bulbs *A* and *B*
(*b*) The intensity of bulb *C*
(*c*) The current drawn from the battery
(*d*) The voltage drop across each bulb
(*e*) The power dissipated in the circuit

5. For the circuit shown, calculate (*a*) the current in the 2-Ω resistor and (*b*) the potential difference between points *P* and *Q*.



Mazur, E. Peer Instruction: A User's Manual, New Jersey: Prentice Hall, Inc., (1997)

ConcepTest

- Short conceptual questions on the subject being disscused.
- It should be:

1. focus on a single concept,
2. not be solvable by relying on equations,
3. have adequate multiple-choice answers,
4. be clearly defined,
5. be neither too easy not too difficult.

Mazur, E. Peer Instruction: A User's Manual, New Jersey: Prentice Hall, Inc., (1997)

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ConcepTest

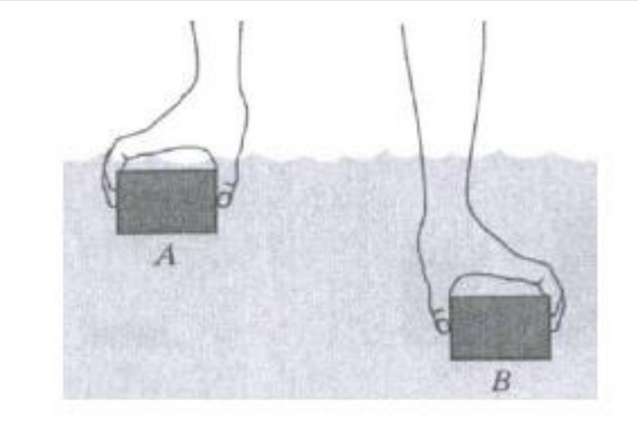
- Each ConcepTest has the following general format:

1. Question posed 1 min
2. Students given time to think 1 min
3. Students record individual answers
4. Students convince their neighbors (peer instruction)1-2 min
5. Students record revised answers
6. Feedback to teacher – Tally of answers
7. Explanation of correct answer 2+min

Mazur, E. Peer Instruction: A User's Manual, New Jersey: Prentice Hall, Inc., (1997)

Example - *Boyancy*

Imagine holding two identical bricks under water. Brick *A* is just beneath the surface of the water, while brick *B* is at a greater depth. The force needed to hold brick *B* in place is



1. larger than
2. the same as
3. smaller than

the force required to hold brick *A* in place.

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Frequently asked questions

1. Will we be forced to cover less material if students talk to each other more during the class?
2. Will not the application of methods increase the difference in the achievements of students of advanced and regular groups?
3. The method works among Harvard students, but will it work in my class?
4. Will I, as a lecturer, successfully apply the method?
5. How long does it take to change the lecture format?

Mazur, E. Peer Instruction: A User's Manual, New Jersey: Prentice Hall, Inc., (1997)

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Recommandations

1. Convince yourself (and colleagues)!
2. Motivate students.
3. Change the lecture format.
4. Change exams.
5. Problem solving (equal representation of traditional and conceptual tasks).
6. Seriously treat homework!

Mazur, E. Peer Instruction: A User’s Manual, New Jersey: Prentice Hall, Inc., (1997)

Sample lecture

- 90 min lecture about Newton’s laws:

1. Newton’s first law,
2. Definitions of force and mass,
3. Newton’s second law,
4. Newton’s third law.

Mazur, E. Peer Instruction: A User’s Manual, New Jersey: Prentice Hall, Inc., (1997)

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Short reading quiz

1. Which of these laws is not one of Newton's:

A. To every reaction there is an opposed equal reaction.

B. *F=ma*.

C. All objects fall with equal acceleration.

D. In the absence of a net external force, objects at rest stay at rest and objects in uniform motion stay in uniform motion.

2. The law of inertia

A. is not covered in the reading assignment,

B. expresses tendency of bodies to maintain their state of motion,

C. is Newton's third law.

3. "Impulse" is

A. not covered in the reading assignment,

B. another name for force,

C. another name for acceleration.

Lecture – after establishing the relationship between forces and acceleration – *ConcepTest* 1

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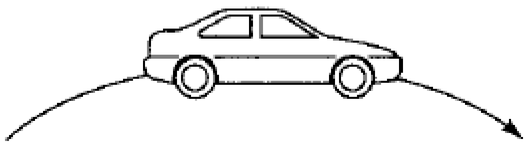
A car rounds a curve while maintaining a constant speed.



Is there a net force on the car as it rounds the curve?

1. No—its speed is constant.
2. Yes.
3. It depends on the sharpness of the curve and the speed of the car.

Figure 5.2 *ConcepTest* on Newton's first law. Choice 2 is correct. Response statistics: 1: 3%, 2: 96%, 3: 1%.

Continuation of lecture – definition of concepts of force and mass and formulation of Newton's second law.

Pose *ConcepTest* 2.

NOTE: Avoid (at all cost!) using equations.

A constant force is exerted on a cart that is initially at rest on an air track. Friction between the cart and the track is negligible. The force acts for a short time interval and gives the cart a certain final speed.

To reach the same final speed with a force that is only half as big, the force must be exerted on the cart for a time interval

1. four times as long as
2. twice as long as
3. equal to
4. half as long as
5. a quarter of

that for the stronger force.

Figure 5.3 *ConcepTest* on force. Choice 2 is correct. Response statistics before (after) discussion: 1: 16% (5%), 2: 65% (83%), 3: 19% (12%). Confidence before (after) discussion: pretty sure: 50% (71%); not quite sure: 43% (25%); just guessing: 7% (4%).

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ConcepTest 3

A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed.

The same force is exerted for the same length of time on another cart, also initially at rest, that has twice the mass of the first one. The final speed of the heavier cart is

1. one-fourth
2. four times
3. half
4. double
5. the same as

that of the lighter cart.

Figure 5.4 *ConcepTest* on force. Choice 3 is correct. Response statistics before (after) discussion: 1: 10% (1%), 3: 90% (99%). Confidence: pretty sure: 64% (95%); not quite sure: 34% (4%); just guessing: 2% (1%).

ConcepTest 4

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A constant force is exerted for a short time interval on a cart that is initially at rest on an air track. This force gives the cart a certain final speed.

Suppose we repeat the experiment but, instead of starting from rest, the cart is already moving in the direction of the force at the moment we begin to apply the force. After we exert the same constant force for the same short time interval, the increase in the cart's speed

1. is equal to two times its initial speed.
2. is equal to the square of its initial speed.
3. is equal to four times its initial speed.
4. is the same as when it started from rest.
5. cannot be determined from the information provided.

Figure 5.5 *ConcepTest* on force. Choice 4 is correct. Response statistics: 1: 10%, 2: 3%, 3: 5%, 4: 82%. Confidence: pretty sure: 63%; not quite sure: 35%; just guessing: 2%.

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Formulation of Newton’s third law.
ConcepTest 5

A locomotive pulls a series of wagons. Which is the correct analysis of the situation?

1. The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backward on the locomotive.

2. Because action always equals reaction, the locomotive cannot pull the wagons—the wagons pull backward just as hard as the locomotive pulls forward, so there is no motion.

3. The locomotive gets the wagons to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.

4. The locomotive’s force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large while the backward frictional force on the wagons is small.

5. The locomotive can pull the wagons forward only if it weighs more than the wagons.

Figure 5.6 *ConcepTest* on Newton’s third law. Choice 4 is correct. Response statistics before (after) discussion: 1: 14% (7%), 2: 2% (2%) 4: 74% (86%), 5: 9% (5%). Confidence before (after) discussion: pretty sure: 59% (71%); not quite sure: 36% (26%); just guessing: 5% (3%).

Force Concept Inventory (*FCI*)

Hestenes, D., Wells, M. and Swackhamer, G. (1992), Force Concept Inventory, Phys. Teach., 33(3), 141-151.

Table I . Newtonian Concepts in the Inventory.

	Inventory Item
0. Kinematics	
Velocity discriminated from position	20E
Acceleration discriminated from velocity	21D
Constant acceleration entails	
parabolic orbit	23D, 24E
changing speed	25B
Vector addition of velocities	(7E)
1. First Law	
with no force	4B, (6B), 10B
velocity direction constant	26B
speed constant	8A, 27A
with cancelling forces	18B, 28C
2. Second Law	
Impulsive force	(6B), (7E)
Constant force implies constant acceleration	24E, 25B
3. Third Law	
for impulsive forces	2E, 11E
for continuous forces	13A, 14A
4. Superposition Principle	
Vector sum	19B
Cancelling forces	(9D), 18B, 28C
5. Kinds of Force	
5S. Solid contact	
passive	(9D), (12 B,D)
Impulsive	15C
Friction opposes motion	29C
5F. Fluid contact	
Air resistance	22D
buoyant (air pressure)	12D
5G. Gravitation	5D, 9D, (12B,D), 17C, 18B, 22D
acceleration independent of weight	1C, 3A
parabolic trajectory	16B, 23D

Table II. A Taxonomy of Misconceptions Probed by the Inventory. Presence of the misconceptions is suggested by selection of the corresponding Inventory Item.

	Inventory Item
0. Kinematics	
K1. position-velocity undiscriminated	20B,C,D
K2. velocity-acceleration undiscriminated	20A; 21B,C
K3. nonvectorial velocity composition	7C
1. Impetus	
I1. impetus supplied by "hit"	9B,C; 22B,C,E; 29D
I2. loss/recovery of original impetus	4D; 6C,E; 24A; 26A,D,E
I3. impetus dissipation	5A,B,C; 8C; 16C,D; 23E; 27C,E; 29B
I4. gradual/delayed impetus build-up	6D; 8B,D; 24D; 29E
I5. circular impetus	4A,D; 10A
2. Active Force	
AF1. only active agents exert forces	11B; 12B; 13D; 14D; 15A,B; 18D; 22A
AF2. motion implies active force	29A
AF3. no motion implies no force	12E
AF4. velocity proportional to applied force	25A; 28A
AF5. acceleration implies increasing force	17B
AF6. force causes acceleration to terminal velocity	17A; 25D
AF7. active force wears out	25C,E
3. Action/Reaction Pairs	
AR1. greater mass implies greater force	2A,D; 11D; 13B; 14B
AR2. most active agent produces greatest force	13C; 11D; 14C
4. Concatenation of Influences	
CI1. largest force determines motion	18A,E; 19A
CI2. force compromise determines motion	4C, 10D; 16A; 19C,D; 23C; 24C
CI3. last force to act determines motion	6A; 7B; 24B; 26C
5. Other Influences on Motion	
CF. Centrifugal force	4C,D,E; 10C,D,E
Ob. Obstacles exert no force	2C; 9A,B; 12A; 13E; 14E
Resistance	
R1. mass makes things stop	29A,B; 23A,B?
R2. motion when force overcomes resistance	28B,D
R3. resistance opposes force/impetus	28E
Gravity	
G1. air pressure-assisted gravity	9A; 12C; 17E; 18E
G2. gravity intrinsic to mass	5E; 9E; 17D
G3. heavier objects fall faster	1A; 3B,D
G4. gravity increases as objects fall	5B; 17B
G5. gravity acts after impetus wears down	5B; 16D; 23E

Sample from *FCI*

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Force Concept Inventory

1. Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two story building at the same instant of time. The time it takes the balls to reach the ground below will be:

   (A) about half as long for the heavier ball.
   (B) about half as long for the lighter ball.
   (C) about the same time for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long.
   (E) considerably less for the lighter ball, but not necessarily half as long.

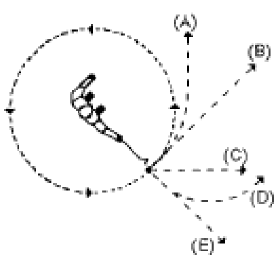
2. Imagine a head-on collision between a large truck and a small compact car. During the collision,

   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car doesn't exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the other, roll off of a horizontal table with the same speeds. In this situation:

   (A) both balls impact the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
   (C) the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
   (D) the heavier ball hits considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
   (E) the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4. A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram to the right. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.

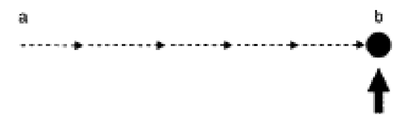


1

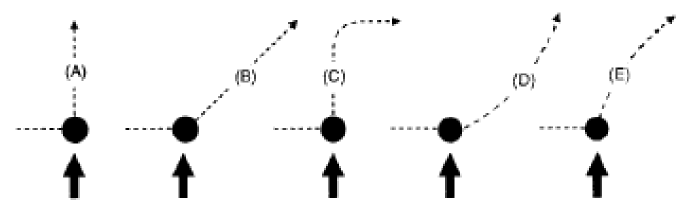
5. A boy throws a steel ball straight up. **Disregarding any effects of air resistance**, the force(s) acting on the ball until it returns to the ground is (are):

   (A) its weight vertically downward along with a steadily decreasing upward force.
   (B) a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
   (C) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
   (D) a constant downward force of gravity only.
   (E) none of the above, the ball falls back down to the earth simply because that is its natural action.

* **Use the statement and diagram below to answer the next four questions:**
* **The diagram depicts a hockey puck sliding, with a constant velocity, from point "a" to point "b" along a frictionless horizontal surface. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.**



6. Along which of the paths below will the hockey puck move after receiving the "kick" ?



7. The speed of the puck just **after** it receives the "kick"?

   (A) Equal to the speed "v_0" it had before it received the "kick".
   (B) Equal to the speed "v" it acquires from the "kick", and independent of the speed "v_0".
   (C) Equal to the arithmetic sum of speeds "v_0" and "v".
   (D) Smaller than either of speeds "v_0" or "v".
   (E) Greater than either of speeds "v_0" or "v", but smaller than the arithmetic sum of these two speeds.

2

Hestenes, D., Wells, M. and Swackhamer, G. (1992), Force Concept Inventory, Phys. Teach., 33(3), 141-151.

Electricity Concept Test (ECT)

- Bilal, E., Erol, M. (2009), Investigating Students' Conceptions of Some Electricity Concepts, Lat. Am. J. Phys. 3(2), 193-201.

TABLE I. Test items diversity to the sub-topics

Items	*Sub-Topics*
1,2	Electrical force
3,4,5	Motion in an electric field
6,7,8	Conductors and insulator in an electric field
9,10,11	Charge transfer
12,13,14	Work between equipotential lines
15,16,17	Charging and discharging in a DC circuit
18,19,20	Current in a DC circuit
21,22,23	Charging and discharging of a capacitor

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Measuring students’ conceptual understanding of wave optics: A Rasch modeling approach

Vanes Mešić, Knut Neumann, Ivica Aviani, Elvedin Hasović, William J. Boone, Nataša Erceg, Vladimir Grubelnik, Ana Sušac, Džana Salibašić Glamočić, Marin Karuza, Andrej Vidak, Adis Alihodžić, and Robert Repnik

Phys. Rev. Phys. Educ. Res. **15**, 010115 – Published 25 February 2019

- List of students' misconceptions and difficulties in wave optics
- Model of the learning path in wave optics
- Expert survey within the initial stage of validation
- Final field testing survey
- Detailed description of the wave physics curricula at the sampled universities

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Some of comments on *PEER INSTRUCTON*

- “I found this approach to be entirely different from anything I have seen. It is highly provocative and the author’s style is very engaging.” – Mark W. Holts, Texas Tech University

- “I have been using Mazur’s *Peer Instruction* methods. The *ConcepTests* and ensuing discussions have certainly improved the atmosphere in the classroom, and both students and I appreciate the instant feedback and chance to confront misconceptions.” – Joel R. Primack, University of California, Santa Cruz

- “I am familiar with Mazur’s effort and am a great fan of using some form of *Peer Instruction* which Mazur has developed. At Rensselaer, we are using this technique. The *Peer Instruction* manual is wonderful in that it describes the process in a way which I think will encourage others to adopt the technique.” – Leo. J. Schowalter, Rensselaer Polytechnic Institute

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