College Students' Conceptual Understanding of the Concepts of Force and Energy: Comparisons with Earlier Studies

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Abstract

The research reported here investigated the level of alternative conceptions of the concepts of force and energy that exist among the college students, and junior high school in Tacloban City, Leyte, Philippines. In this study, the researcher compared a sample of 67 college students from the 2017-2018 school year with an earlier study of 83 grade 10 junior high school students from the 1987-1988 school year in Tacloban City, Leyte Philippines. The instruments used in the study are the test used in the research project of the Asia-Pacific Teachers and Educators Association (APPTEA) (see Appendix A) and the questionnaire developed by R. Duit of West Germany (Appendix B). The research findings concluded that there are persistent alternative conceptions in college students that are similar to the alternative conceptions found in the previous study. This research recommends that both college students, high school and elementary students in the Philippines be exposed to a metacognitive strategy such as inquiry-based approaches, hands-on activity, 7E's innovative approaches to introduce a variety of teaching skills and at the same time create student-centered learning.

Introduction

Some physics teachers at the secondary and tertiary level in the Philippines often have an intuitive or informal knowledge of learning difficulties of their students. Such knowledge is usually based on common wrong answers or solutions given in examinations, laboratory reports, and recitations. It is evident from the literature that students of different educational backgrounds and different ages have basic preconceptions or misconceptions about force and energy concepts that affect student' further learning or achievements (Clement, 1982; Eckstein & Shemesh, 1993a & 1993b; Halloun & Hestenes 1985; Maloney, 1984; Palmer, 1997; Poon, 1993; Thijs, 1992, Bransford, Brown, & Cocking, 1999; Demirci, 2001). However, in the Philippines, systematic assessment or investigation of students' learning difficulties or notions about physics concepts is hardly done, particularly at the college level.

This study describes an initial understanding of misunderstandings in science and focuses on the concepts of force and energy. The participants are science and engineering majors in a university, junior high school, and elementary students of Tacloban City, Leyte. The instruments in the study are the test used in the research project of the Asia-Pacific Teachers and Educators Association (APPTEA) (Appendix A) and the questionnaire developed by R. Duit (1981) of West Germany (Appendix B).

Literature review

Over the past decade, physicists, psychologists and science educators have been conducting research that has yielded detailed information about how students learn physics. Some researchers used physics as a context for examining cognitive processes and approaches to problem-solving. For others, the primary emphasis has been on conceptual understanding in a particular area of Physics such as mechanics. The results show that similar difficulties occur among students of different ages and ability, in spite of formal study in physics. The persistence of these difficulties suggests that they are not easily overcome, and need to be addressed explicitly during instruction. The focus of this study is limited to research on the learning and teaching of some of the basic concepts in force and energy.

The study of physics begins with mechanics being the oldest and the most fundamental branch of physics. It deals with such ideas as inertia, motion, force and energy. Many of the principles used in physics today were developed over a hundred years ago. It helps answer many practical questions and provides the foundation for much of the rest of the development of physics.

It has been well documented that beginning physics students often find physics difficult. One of the reasons for this is that the way in which physics deals with everyday experiences gives the student an intuitive idea about how the universe works and how to make inferences or draw conclusions (Adams et al., 2006). These concepts are often based directly upon what the senses detect. As such, the student usually arrives into a physics class for the first time with alternative conceptions about the nature of physical knowledge that is counter-intuitive to what they are exposed to in the course.

Clement (1982) and Finkelstein (2005) intimated that the students in physics courses experience significant conceptual difficulties at a qualitative level in addition to the challenge of learning quantitative concepts. Patterns in the errors on qualitative problems indicate that errors are not random. Pretest and interviews given before the course showed some of the same errors patterns and indicated that the students are entering courses with certain preconceptions. These are conceptions which have formed before formal instruction in physics.

In studying student understanding of basic concepts of physics, much has been revealed about what students know and how they learn (Perkins et al., 2005; Thornton, Kuhl, Cummings, & Marx, 2009). The crucial element is that students are not 'blank slates'. Their experience of the world leads them to develop many concepts of their own about how the world functions. These concepts are often not easily matched with those that are being taught in a physics course, and students' previous misconceptions may make it difficult for them to build the conclusion the teacher desires (Gray, Adams, Wieman, & Perkins, 2008).

Difficulties often arise when students' ideas differ from the definitions accepted by experts. These incorrect ideas are generally called misconceptions or alternative conceptions. Schmidt (1997) wrote that if students are given a problem to solve they must understand the concepts involved because students actively and persistently hold alternative conceptions. Hence, misconceptions differ from mistakes, which can be recognized by the students themselves when presented with an accepted concept.

Aristotle was the first to systematically develop an explicit formulation for common sense belief about physical phenomena and organize them into the coherent conceptual system. According to Pfundt and Duit, (1994) that over the centuries physics developed and the meaning of physics concepts became different in subtle and sophisticated ways from common sense concepts of physics. The belief systems of students untutored in physics are sometimes characterized as Aristotelian.

Common sense misconceptions are not arbitrary or trivial mistakes. Indeed, every one of the misconceptions about force and energy common among students today was seriously advocated by leading intellectuals in pre-Newtonian times (Halloun & Hestenes, 1985). Given that Aristotle and Galileo recognised the complexity of physics concepts, then it is not surprising to find it is a problem for ordinary students today.

Research methodology

The sample and sampling procedure

The participants are 67 college students of Leyte Normal University, Tacloban City, Leyte, Philippines comprising two entire physics classes. The students whose mean age is 17.7 years are mostly second to third-year college students. Like all Filipino children, Tacloban City residents may enter college at about age 15 to 16 years. Students in the college are scholars of the Philippine government. Purposive sampling was used to select the college and the physics classes.

The samples in the earlier grade 6 and grade 10 junior high school students, are briefly described in the next section.

The instruments

The data were gathered in September 2017 during the laboratory class using two instruments developed by other researchers (Duit; 1981; Osborne & Freberg, 1985; Gunstone, 1988). The instruments are of the paper-and-pencil questionnaire/test type, where students are required to explain their answers. This instrument was formulated in Australia in 1987 for the Asia-Pacific Physics Teachers and Educators Association (APPTEA) project. It was the result of the collective efforts of the representatives of the countries who attended the inaugural meeting of the APPTEA in a workshop sponsored by UNESCO in 1986 in Manila. The pilot testing of this instrument was done in seven countries namely India, Korea, Malaysia, Philippines, Singapore, Thailand and Australia.

The physics concepts studied are restricted by the instruments used. The students had taken up the concepts assessed in the instruments before the administration of the instruments. The first instrument (Gunstone, 1988) is essentially a multiple-choice test, where students are asked to explain their choice (Appendix A). The first set of questions asks the student to indicate the direction of the force at different paths of a ball thrown up and a ball thrown to a person. In the latter case, the student is further asked if forces are acting on the ball other than those given in the diagrams.

The second set of questions in the first instrument asks the student if there is a force acting on a given body, such as a bicycle with a person riding it. The student is asked if there is gravity when someone falls from an airplane, when a person stands on the moon, when a spaceman is near a satellite going around the earth, and when a person swims under water. The final question shows two equal blocks at rest on a pulley with one block lower than the other. The students are asked if one minute later, the blocks would be in the same position, at the same height, or reversed positions.

The data analysis follows that of Gunstone (1988) for comparability of results with two classes of students in Leyte National High School (N = 41) and Sagkahan National High School (N = 42) in Tacloban City, Leyte. These 83 Grade 10 high school students participated in the APPTEA cross-cultural study in October 1987.

The second instrument (Duit, 1981) initially uses word association to determine students' notions of energy. The students are then asked to give an example and a description of energy (Appendix B).

The second type of question asks the students to mark the spot reached by a ball released from a given point on three different curved paths with no friction. The students are asked to provide the reason for their answer.

The third type of question also probes the understanding of conservation of mechanical energy. The student is asked to compare the speed of a ball before and after it rolls over the slopes. The rolling of the ball continues over three slopes of different shapes without friction and any drive of its own. The students are asked to give the reason for their answer. The analysis of students' answers is patterned after that of Duit (1981) to facilitate comparisons with the results of the two classes each of a cross-cultural study conducted in 1981 with two classes each of Grade 6 students (N = 88) and Grade 10 Junior High School students in Tacloban City, Leyte. The college students in the sample are not necessarily graduates of the secondary and elementary schools in the earliest studies.

Discussion

In the following discussion the results are presented in groups according to the physical laws or concepts for which one or more questions were used.

Questions 1 -3: A person throws a ball straight up into the air just a small way.

This is about the *total force* on the ball when: *the ball is on the way up, the ball is just at the top of its flight, and the ball is on the way down.*

On the concept of force, in particular, the force of gravity, the prevailing alternative conceptions among the sample of students from secondary and college levels was that the direction of force follows the direction of motion (Figure 1 and 2, Question 1–3, Appendix A). Furthermore, for the majority of the students, the force acting on a ball thrown straight up is zero at the highest point of its path when it momentarily stops–an indication that the presence of force is associated with having speed. The correct answer was given by a small minority of junior high school (5%) and college (4%) students. This finding is consistent with the findings in the research of Pablico (2010). The research found that the majority of the students equally understood in the presence of the force of throw, the direction of motion is also the same direction of the force. According to Driver (1994) this is a common alternative conceptions of students.

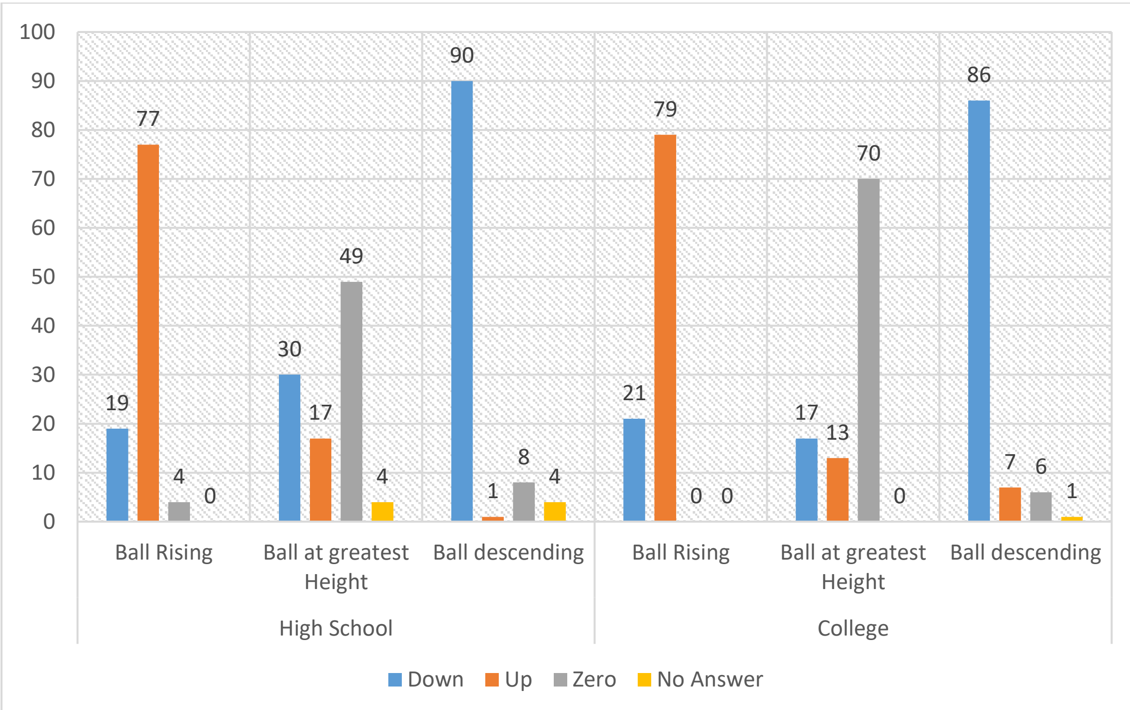


Figure 1: Total force on a ball thrown straight up (percentage responses)

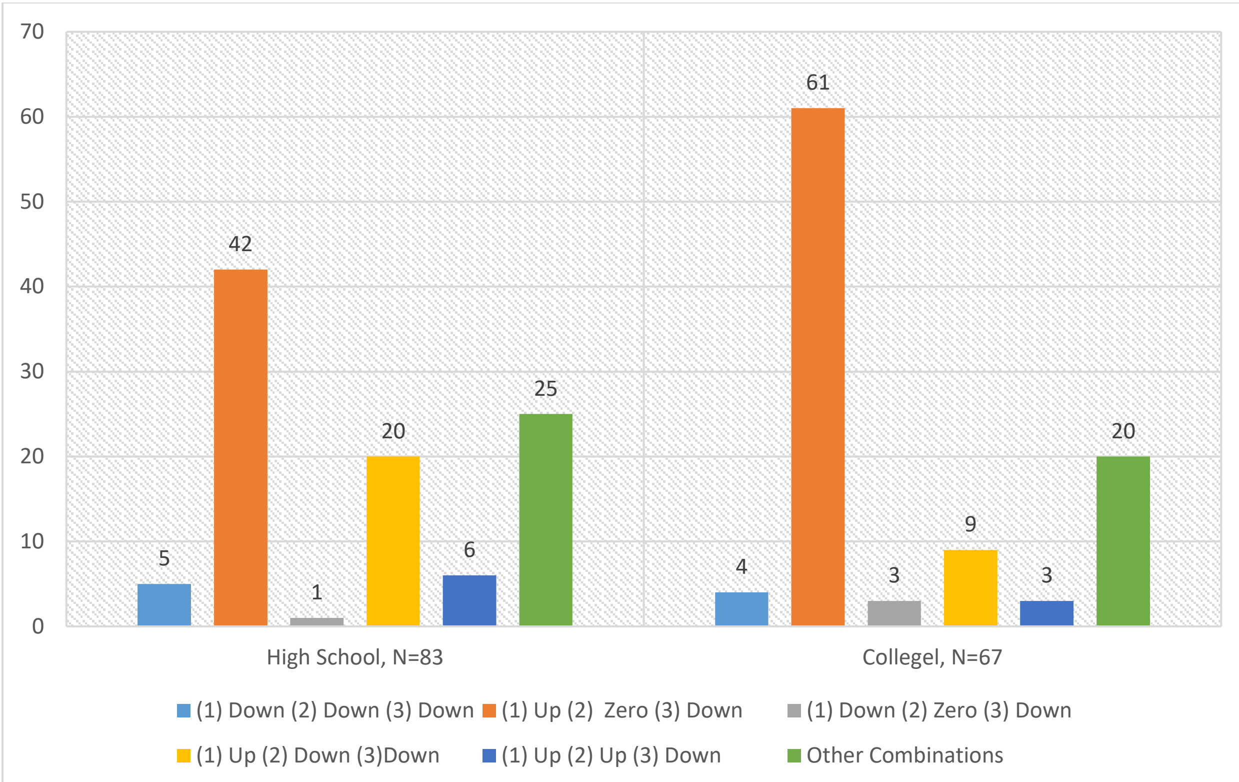
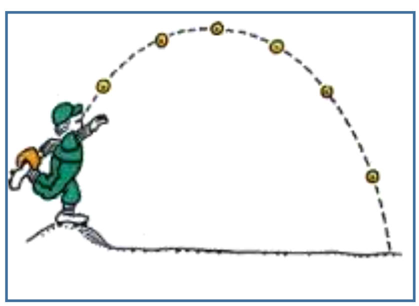


Figure 2: Combined responses to three questions about total force on (1) ball rising vertically, (2) at highest point, and (3) falling vertically (percentage responses)

Questions 4 and 5: The person now throws the ball to someone else. This drawing shows the path the ball travels along.



Questions 4 and 5 are about *all the forces* on the ball. *When the ball is at its highest point and when the ball is on the way down again.*

Another common alternative conception among college and junior high school students is that for a ball thrown to a person (Questions 4-5, Appendix A), the force of the throw still acts on the ball even after it leaves the hand of the thrower (Figure 3). This is again consistent with the study of Pablico, (2010) where the majority of all the respondents believed in the presence of force of the throw.

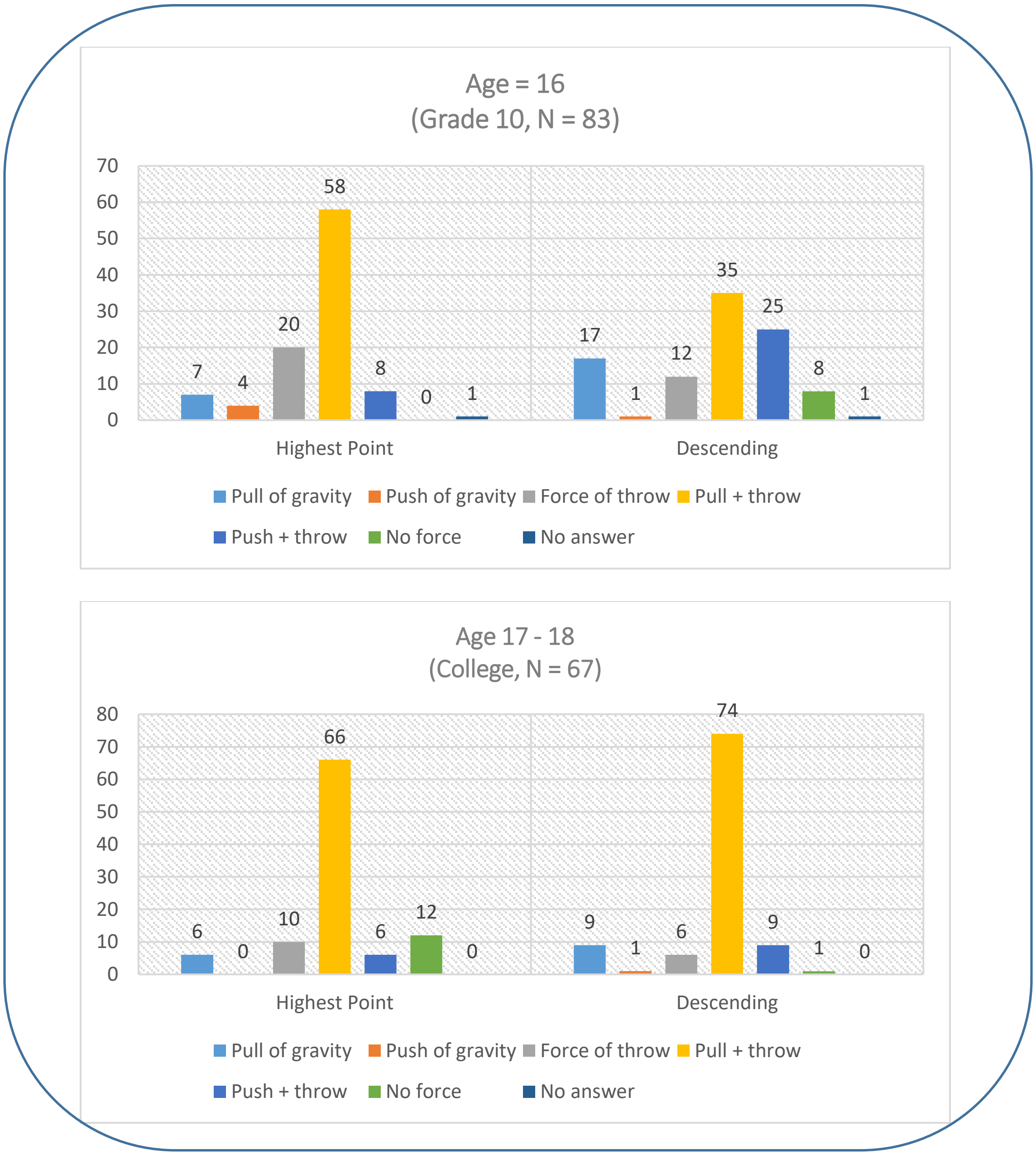


Figure 3: Forces on a ball thrown to a person, at highest point and descending (percentage responses)

Question 6: A person is riding a bicycle. The person is not using the breaks or pedals and is slowing down.

For the forces acting on a bicycle (Question 6, Appendix A) that is slowing down, wherein the person riding does not use the brakes or pedals, the majority of the students at both college and high school levels replied that there is a force acting on the bicycle (Figure 4). The difference between the responses of the two groups of students was not statistically significant. Three of these were found similar to the alternative conceptions found in the study of Pablico, (2010), namely: there is force on the bicycle since it is still moving; there's no force because there's no pedalling and no brakes applied.

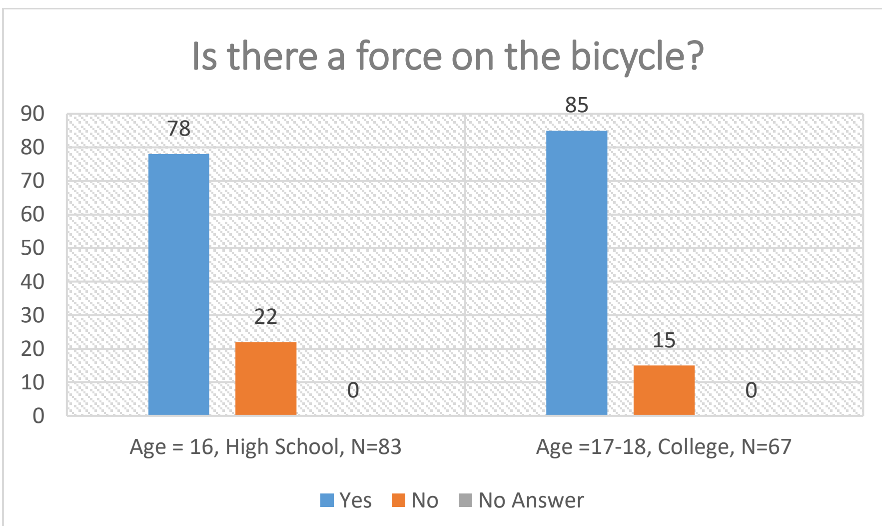


Figure 4: Force on a bicycle slowing down (percentage responses)

Question 7: Is there any *gravity* when you are standing on the earth?

For gravity on the moon (Question 7, Appendix A) which is often discussed in Philippine textbooks as about one-sixth that on earth, still many high school students were uncertain as to whether the gravity is much more, much less than that on earth, or zero (Figure 6). The results are more definitive with the college students, perhaps a result of more instruction, with majority replying, "much less."

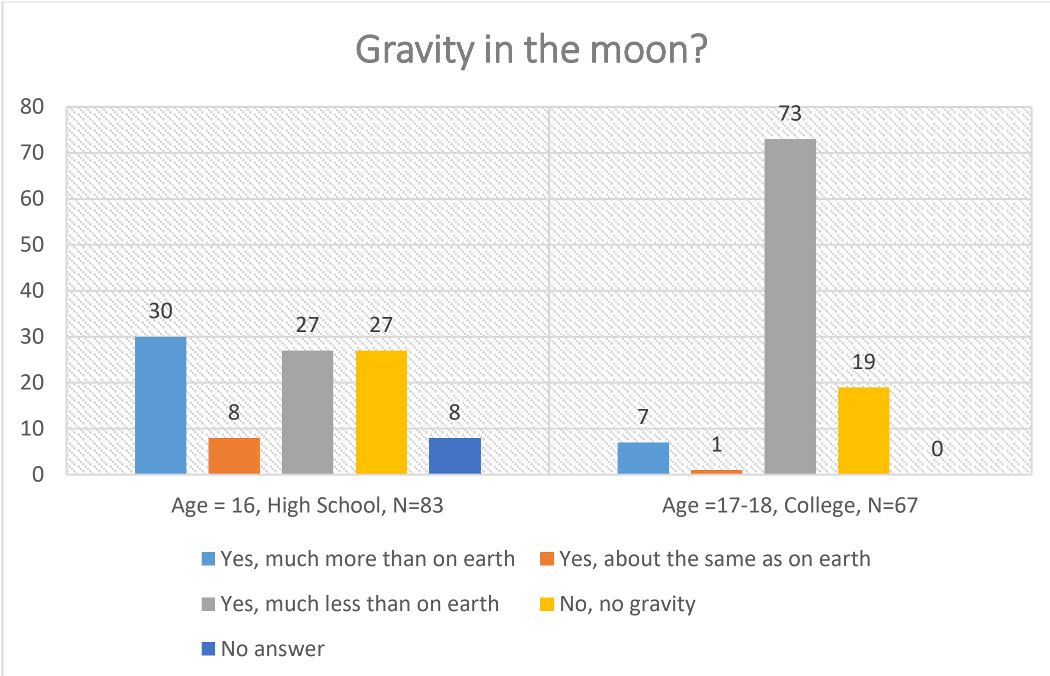


Figure 6: Gravity on the moon (percentage responses)

Question 8: If someone falls from an aeroplane, is there any *gravity?*

The questions on the presence of gravity in different situations yielded interesting results. For someone falling from an airplane, (Question 8, Appendix A) more students at both levels thought of gravity as much less than that on the ground (Figure 5). Perhaps students overestimated the magnitude of the distances involved concerning the ground.

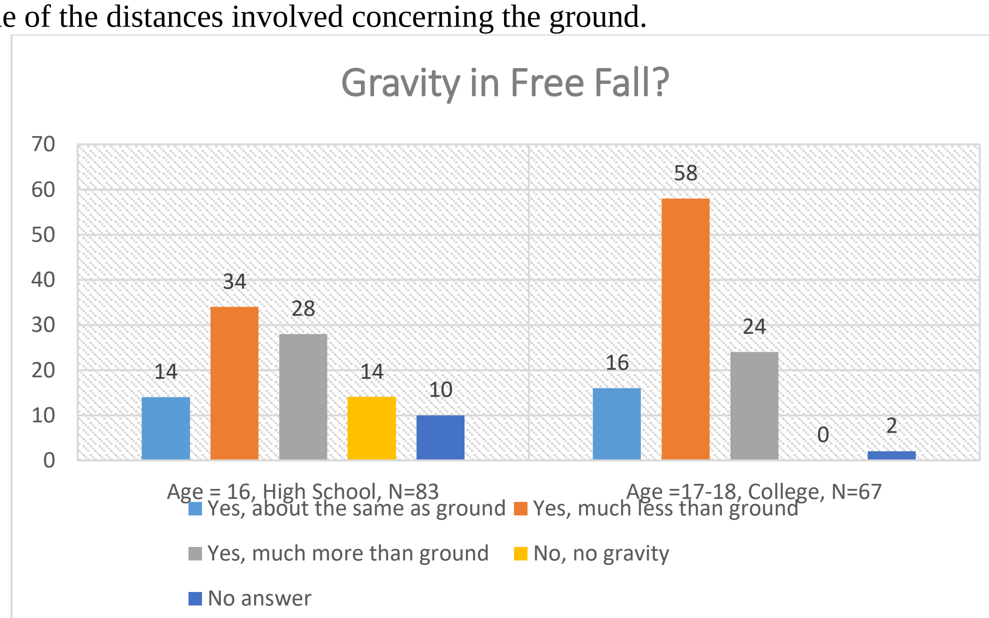


Figure 5: Gravity in free fall (percentage responses)

Question 10: If someone is standing on the moon, is there any *gravity?*

In the case of a spaceman near a satellite orbiting the earth (Question 10, Appendix A), responses of the sample at the two levels are contrasting, with more high school students saying gravity and more college students is saying there is no gravity (Figure 7). This shows that zero net force is interpreted as zero gravity by many students at both levels. This result could be limited to the sample of the study, perhaps a consequence of ambiguous instruction received at the tertiary level.

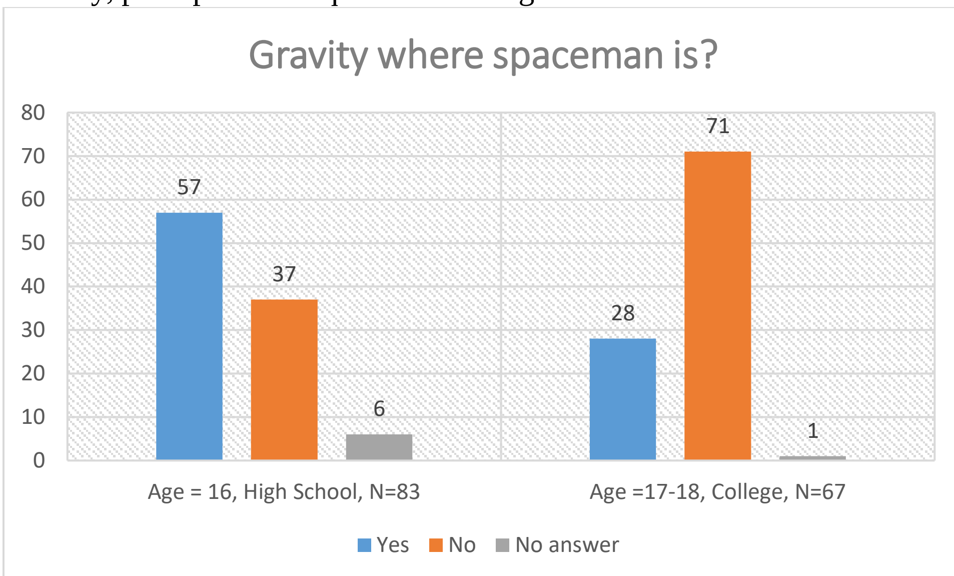


Figure 7: Gravity when in orbit around the earth (percentage responses)

Question 11: Is there any gravity when the person is swimming under water?

For a person swimming underwater (Question 11, Appendix A), equal percentages of high school students believed in the presence of gravity depending on whether the swimmer is going up or down (Figure 8). There seems to be some confusion about the concepts of gravity and buoyancy, and, as in a previous example, the notion of force being in the direction of motion. Possibly a result of added instruction, most of the college students indicated, the presence of gravity.

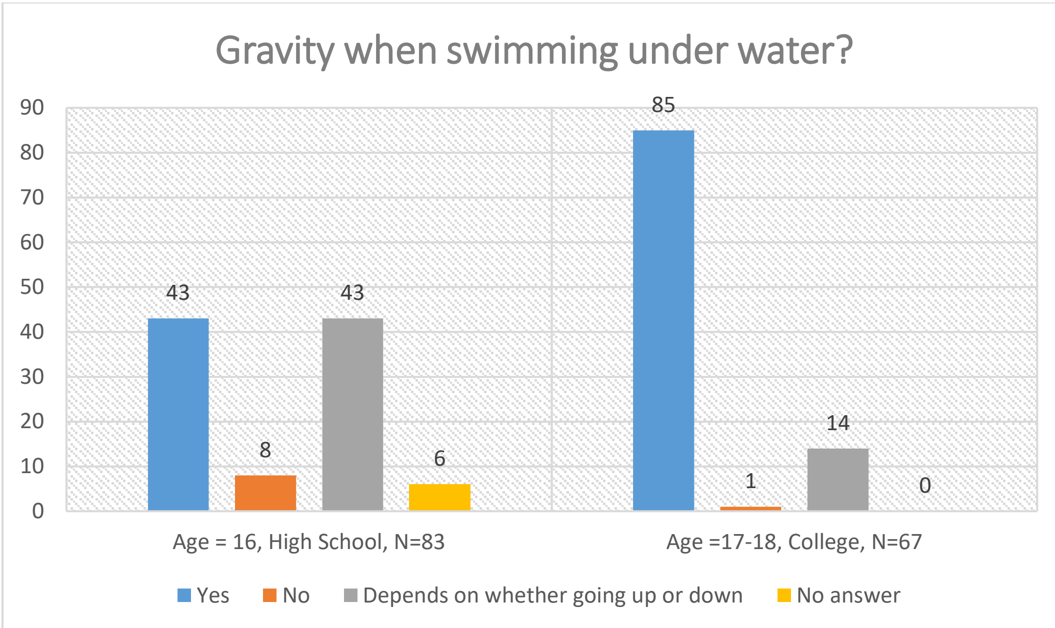
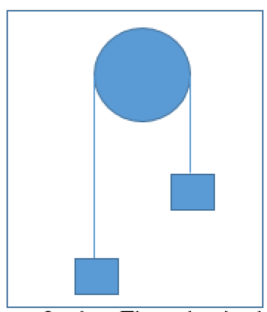
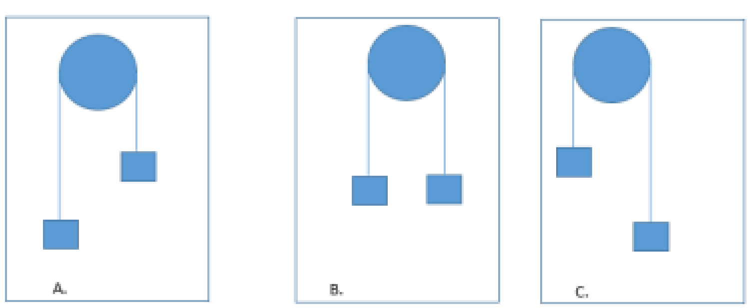


Figure 8: Gravity when swimming under water (percentage responses)

Question 12: Two equal blocks are linked by a piece of string. The string is placed over a pulley, so the blocks are at rest in the positions shown in the picture above.



When we look at the blocks one minute later, which of the three pictures below best shows the positions of the blocks now?



The final question of the position of two blocks on a pulley one minute later, (Question 12, Appendix A) misled many students at both levels even if the locks were stated to be at rest (Figure

9). It seemed difficult for students to perceive two blocks at different levels to be at rest. The common alternative conceptions appears to be that equilibrium is achieved with the two blocks at the same level. This may be due to the common sense perception of conditions of equilibrium of a see-saw or balance.

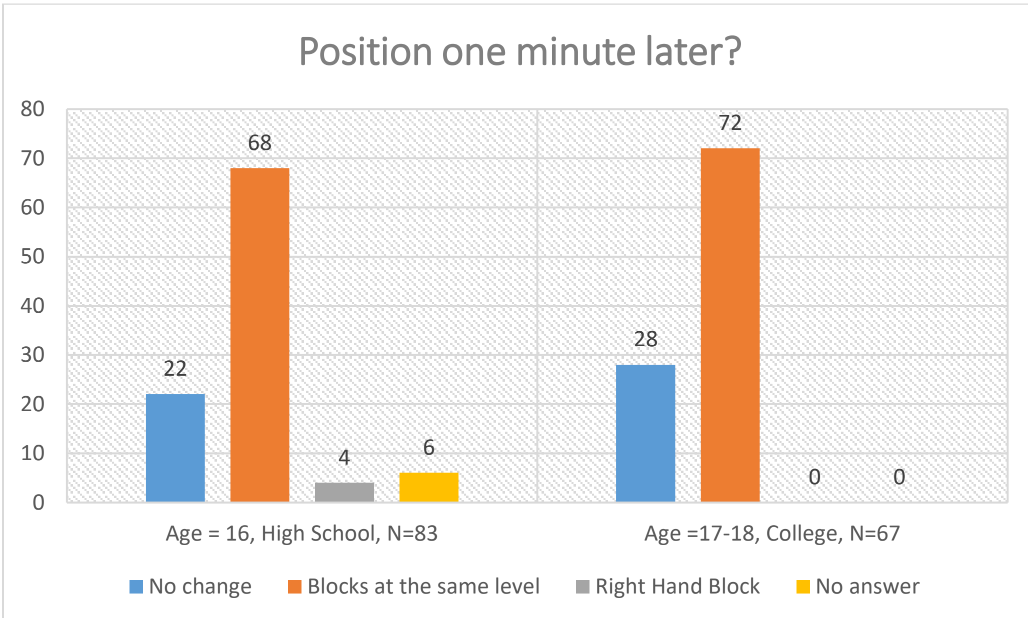


Figure 9: Blocks on a pulley (percentage responses)

The data on energy concepts for college students are compared with students at the elementary and high school levels (Table 1). Three patterns are discernible:

1. *Distinguishing between concepts of energy, force and power.* From Table 10, at the elementary level, students fail to distinguish between three concepts: 'energy as ability to do,' 'force,' and 'power' (Question 1, Appendix B). At the secondary level, students showed correct understanding that force is different from energy, but they fail to understand the distinction between energy and power. At the college level, most students correctly understand energy as 'ability to do work' as distinguished from the concepts of 'force' and 'power.' It appears that the distinction between energy and force is easier to grasp than the finer distinction between energy and power.

Table 1: Description of energy (percentage responses)

Description	Elementary (Grade 6, age 12) N = 84	High School (Grade 10, age 16) N = 89	College (age 17 – 18) N = 67
1. Needed for work/ability to do work	9	41	76
2. Gives force/ Energy is force	7	7	1
3. Needed for power/Energy is power	9	13	1
4. Needed for current/Energy is current	6	1	0
5. Strength	17	10	1
6. Formulas	0	7	5
7. Energy needed for life/activities	38	11	5
8. Energy form	4	6	5
9. Energy conversion/transfer	4	4	5
10. No answer	6	0	1

2. *Experiential associations versus abstract understanding.* Elementary students tended to associate ‘energy’ more with concepts closer to concrete experience such as ‘strength,’ ‘life’ and ‘activities,’ while college students tended to associate ‘energy’ more with abstract like ‘formulas.’

From Figures 10 and 11, grade 6 students sampled mentioned less conceptual associations (38%) than secondary students (55% physical concepts, 10% definitions) and college students (54% physical concepts, 8% definitions, 6% units). The association with ‘strength’ was reduced from 20% in the elementary level to 8% in the college level. When asked to give examples, percentage of students giving physical concepts rose from 1% to 11% (Figure 13) at the elementary and high school level, respectively, to 36% at the tertiary level (Figure 10). However, it is difficult to explain why the percentage giving ‘things’ as examples of energy increased to 21% at the college level.

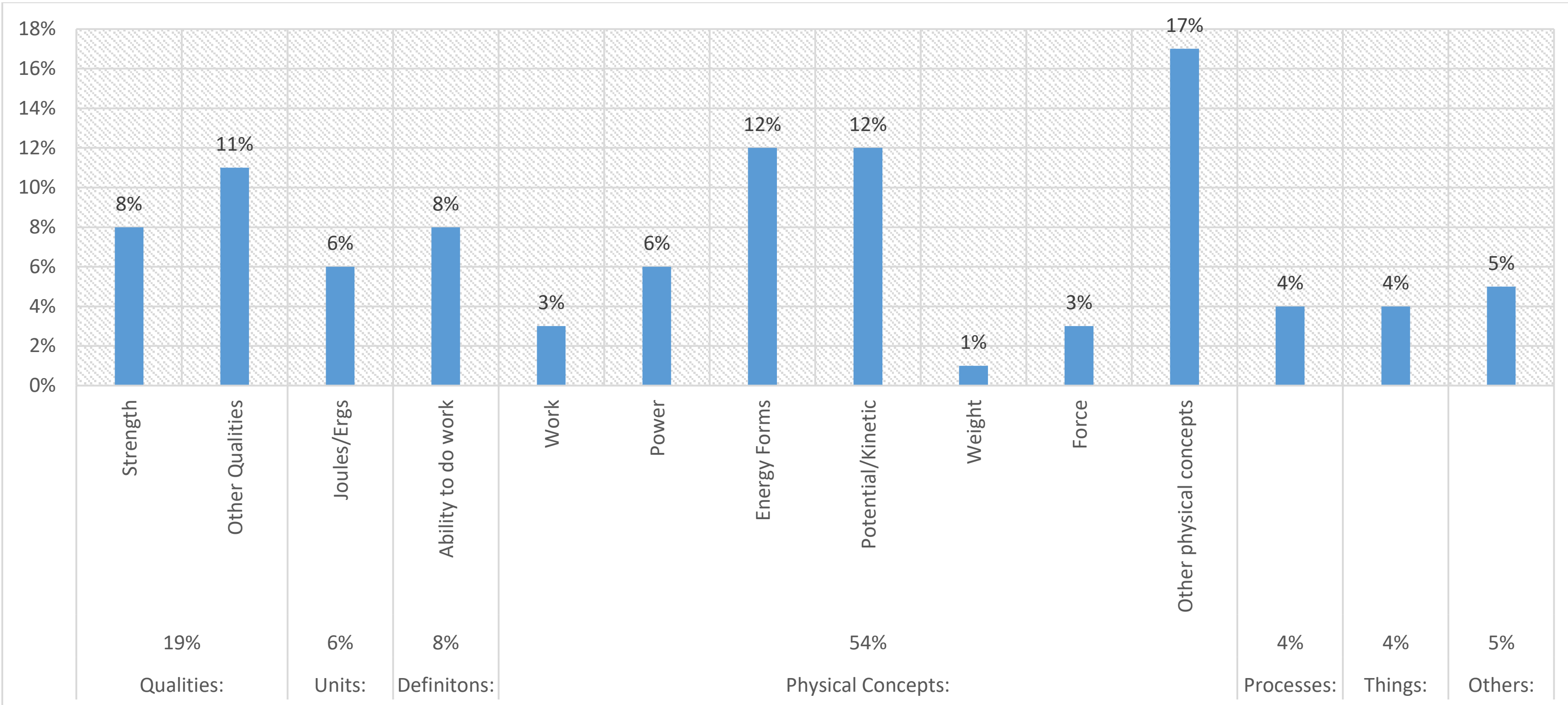


Figure 10: Energy associations (10a)

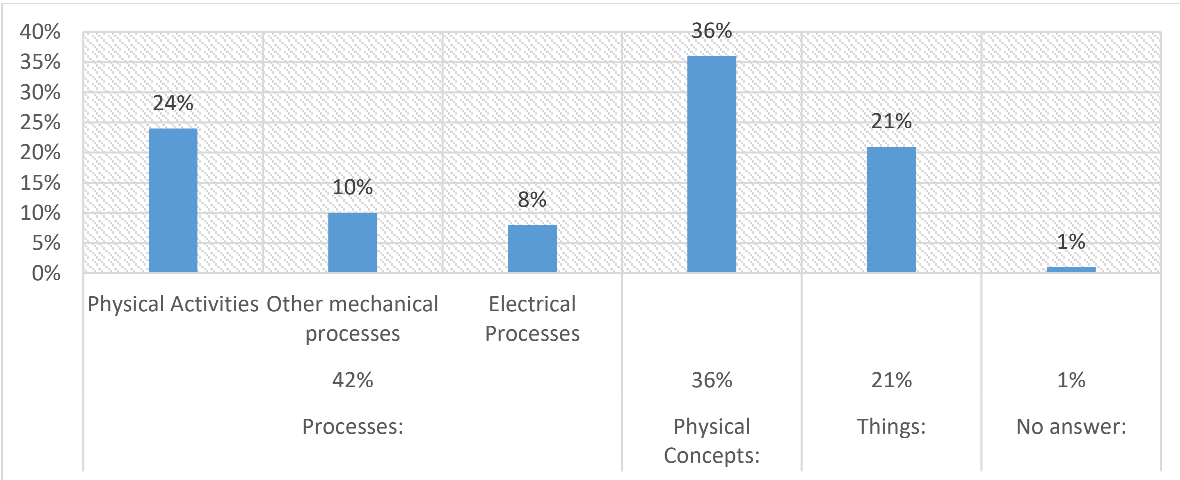


Figure 10: Energy examples (10b)

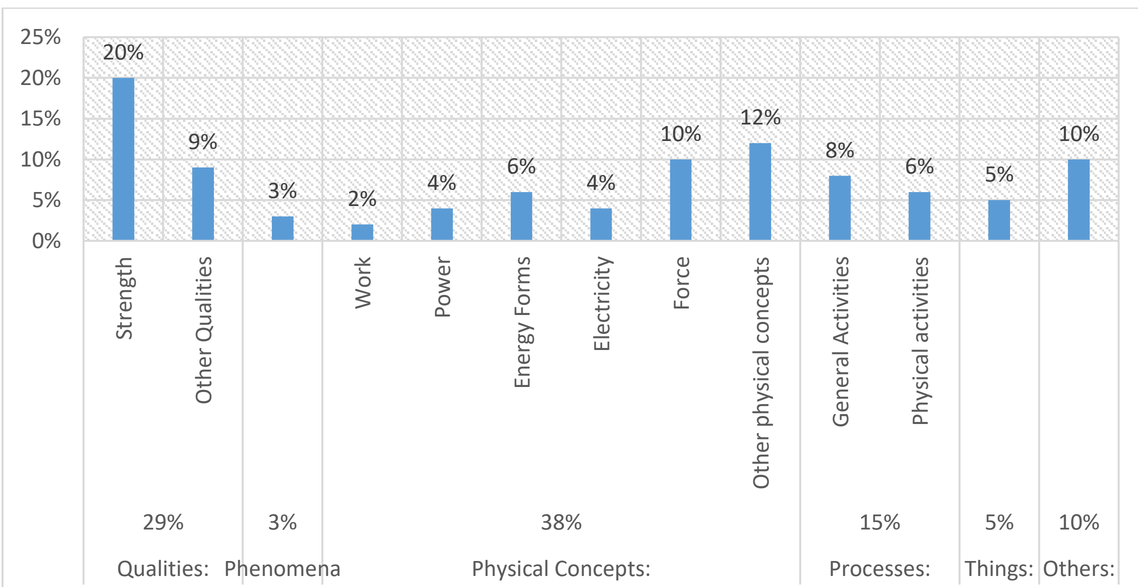


Figure 11: Energy associations (11a) San Jose Elementary School

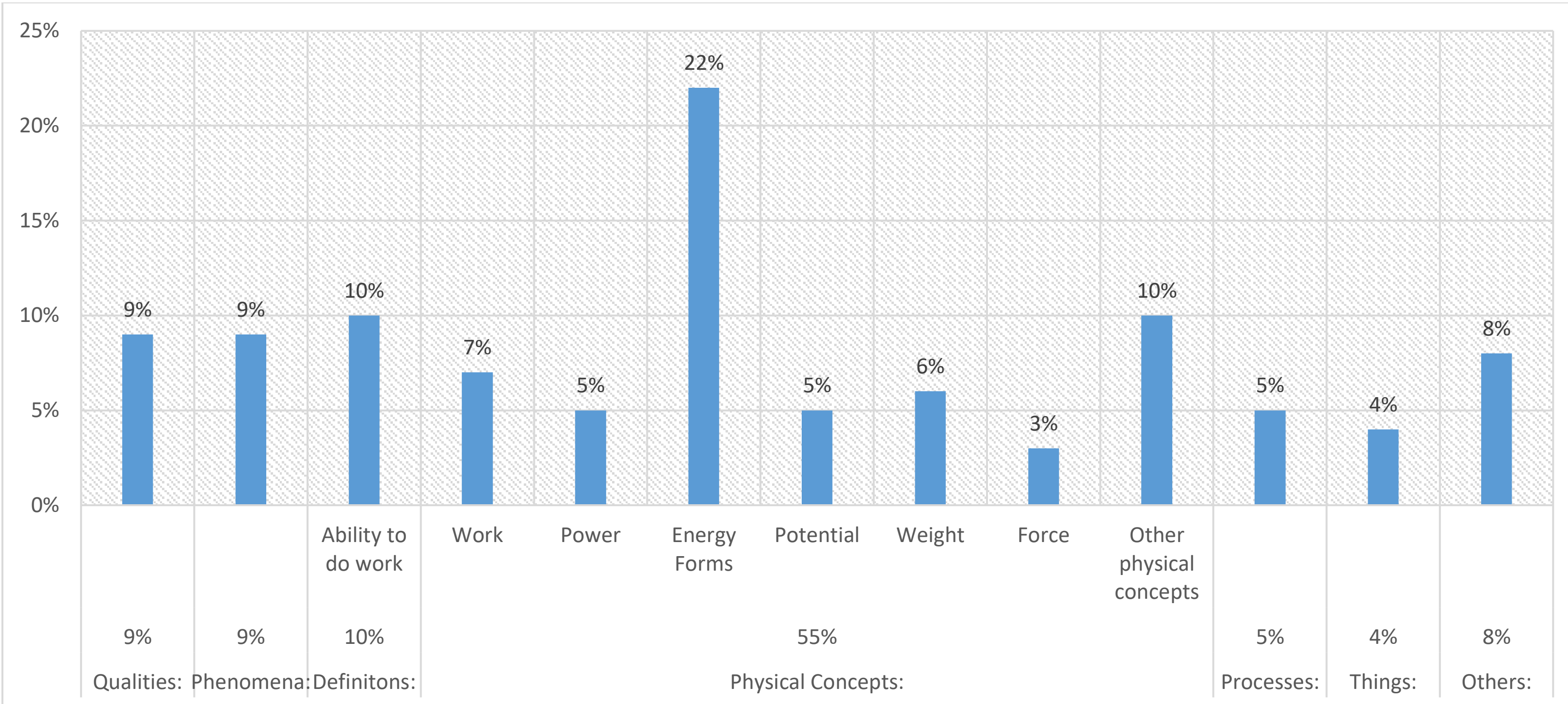


Figure11: Energy associations (11b) grade 10 students

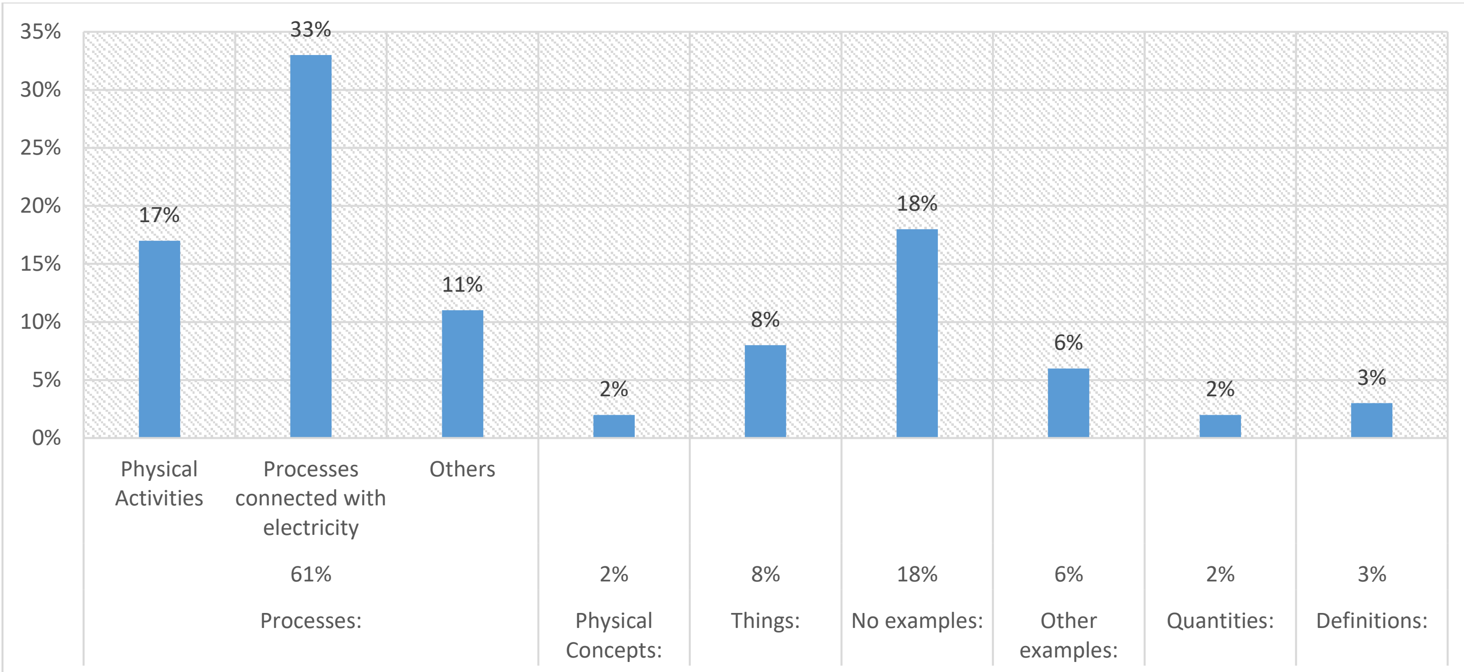


Figure 12: Energy examples (12a) grade 6 - San Jose Elementary School

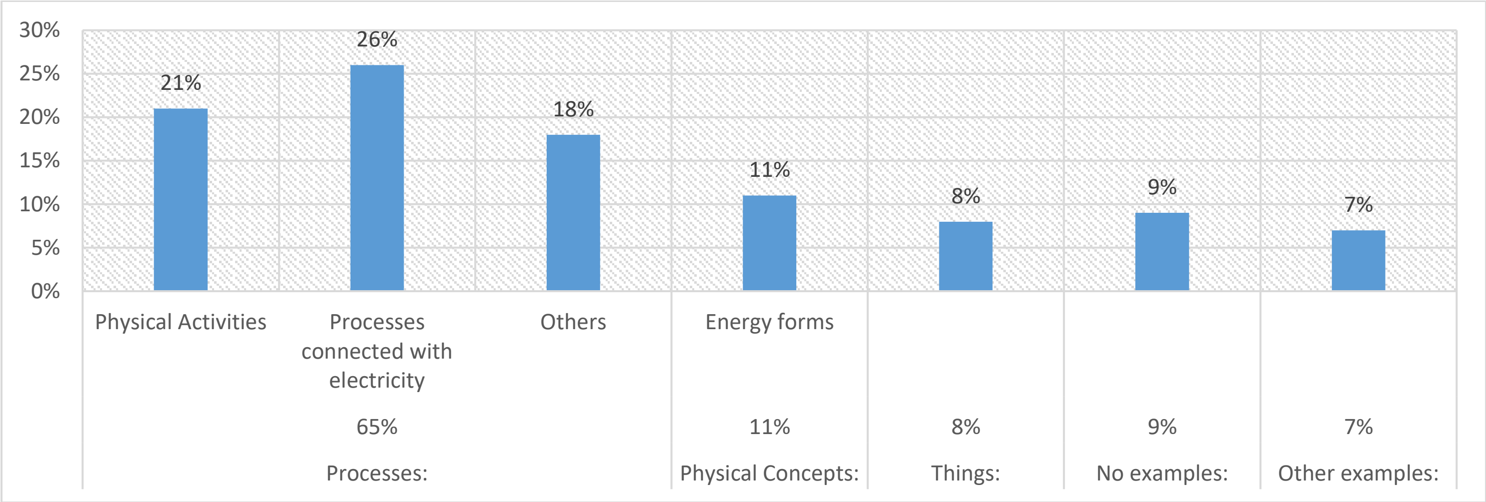


Figure 12: Energy examples of grade 10 (12b)

From an instructional viewpoint, energy can be understood through its properties. Table 2, 3 and 4 (Questions 1 -3, Appendix B) show that most college students understood energy as a quantity through its definition while elementary school students understood energy through a wide range of its properties.

Table 2: Energy associations, description & examples of grade 6 (N = 88 Students)

	Energy Concepts By:		
	Associations	Description	Examples
Energy as quantity	1%	7%	9%
Energy as transferable	-----	3%	9%
Energy in many forms	22%	16%	16%
Energy is convertible from one form to another	-----	1%	22%
Energy is conservative	-----	-----	-----
Value of different energy forms	-----	-----	-----

Table 3: Energy associations, description and examples of grade 10 junior high school (n=89) students

	Energy Concepts By:		
	Associations	Descriptions	Examples
Energy as a quantity	39%	48%	11%
Energy as transferable	----	4%	11%
Energy in many forms	68%	4%	11%
Energy is convertible from one form to another	----	----	29%
Energy is conservative	----	----	----
Value of different energy forms	----	----	----

Table 4: Energy associations, description and examples of college (n=67) students

	Energy Concepts By:		
	Associations	Descriptions	Examples
Energy as a quantity	29%	83%	----
Energy as transferable	----	---	----
Energy in many forms	12%	5%	36%
Energy is convertible from one form to another	----	5%	3%
Energy is conservative	1%	4%	----
Value of different energy forms	----	----	----

3. *Energy in the Philippine local dialect.* The word closest to the concept of energy is *Kusog* in the Binasaya dialect which means strength, and *gahom* in the Binasaya dialect which means power. 'Work' in the local dialects is either *buhat or trabaho*, which connotes 'employment.' There is clearly a possibility that language plays a role in misunderstanding of physics concepts. The teaching of subjects in the content area in the Philippine schools uses bilingual instruction, in this study Binasaya (the native language in Tacloban City, Leyte Philippines) and English combination.

The concept of energy conservation is more abstract than the concept of energy. Alternative conceptions about the former were tested using a ball rolling down and then up a frictionless path (Questions 5a, 5b, and 5c, Appendix B). Answering the question correctly requires additional understanding of the concept of friction and the property of being frictionless. The following observations can be made from responses summarized in Figure 13:

a) The concept that *energy cannot be created* can be understood only by college students, judging from the sampled responses. The percentage of college students choosing 'higher than starting point' in all three paths is nil.

b) At all levels and for all three paths (except tertiary level answers to Path 5a), the predominant response is 'lower than starting point.' This can be explained in two-ways: failure to grasp the concept of energy conservation and/or failure to grasp the concept of 'frictionless,' or the fact that shape and length of path do not affect the assumption of frictionless. There seems to be a persistent alternative conceptions – despite the assumption of zero friction – that the longest and most tortuous path offers greater resistance to motion. In all paths 5a to 5c, even if students' answered 'higher' or 'lower' to first question, they assumed that the ball will have a lower final position. This could indicate a failure to grasp the concept of frictionless. It is also possible that students did not correctly associate the ball reaching 'the same level as starting point' with the concept of energy conservation. In any case, the large percentage of students giving no answer indicates lack of knowledge or certainty among the students.

c) From answers to Question 6a to 6c in Appendix B (Figure 14), students' at all three levels largely missed the right answer. Generally, there were more students with alternative conceptions that those with correct conceptions. The surprising findings is the large percentage among college students answering 'greater than.' Even college students believed that kinetic energy can be created, but from observation (1) (answers to Questions 5a to 5c), they cannot imagine potential energy being created. One instructional implication of this finding is that conservation of energy can best be taught first through the concept of potential energy.

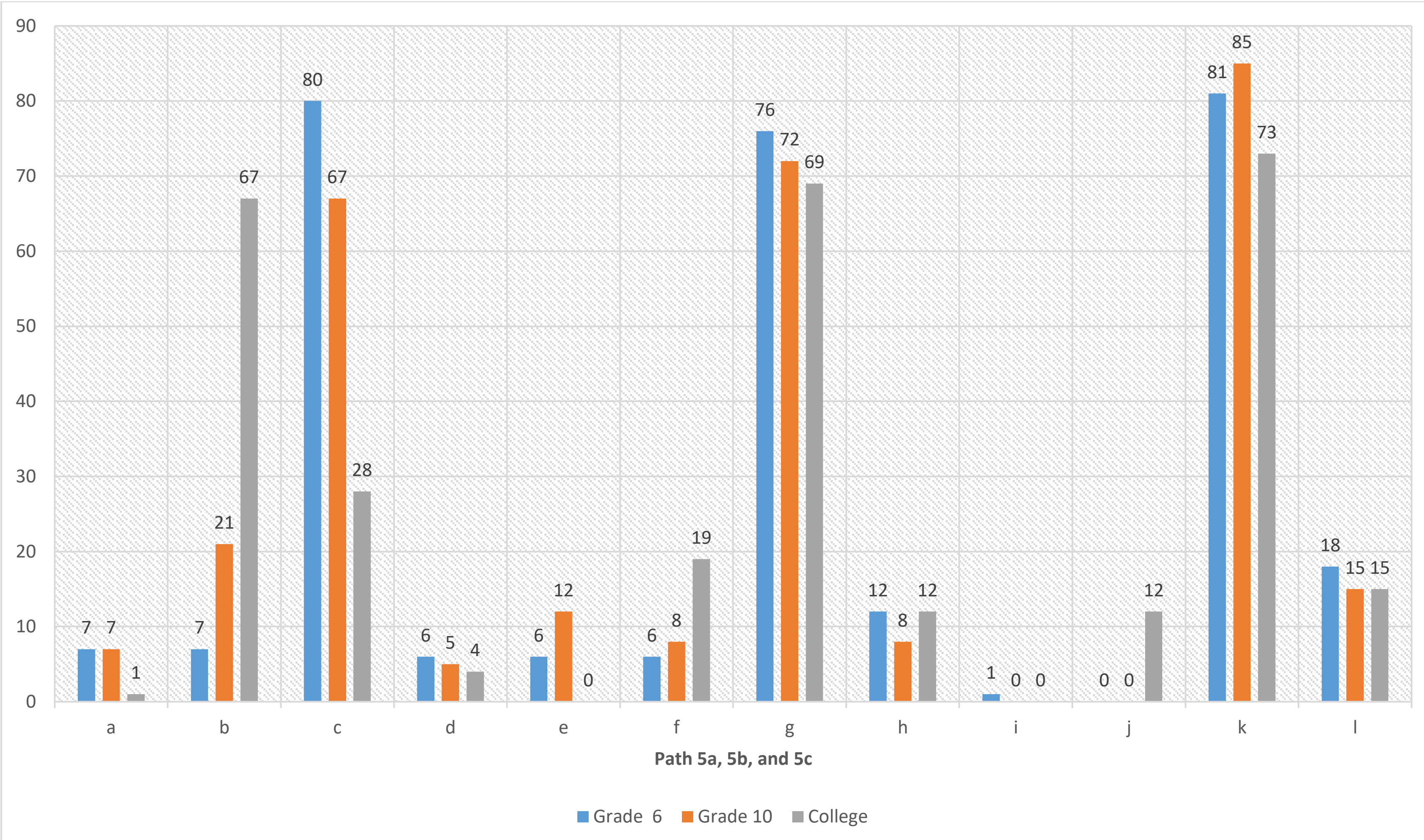


Figure 13: Highest point reached by ball on a curved path without friction (percentage responses) (higher than starting point: a, e, i); (same level as starting point: b, f, j); (lower than starting point: c, g, k); (no answer: d, h, l)

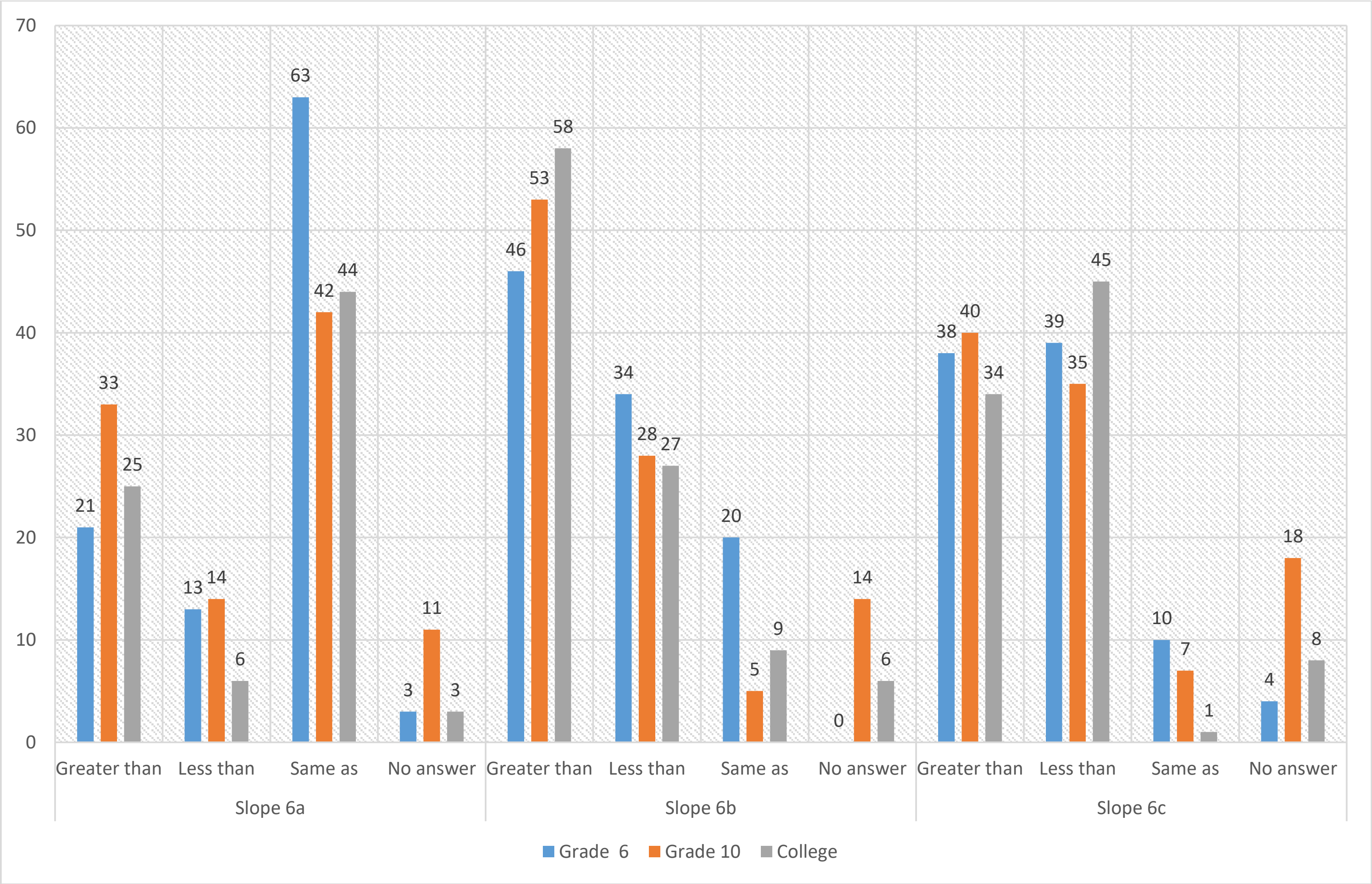


Figure 14: Speed of ball before and after slope without friction (percentage responses)

Conclusions

Additional instruction seems to have no significant effect on understanding of the concept of force by college students compared with high school students. The results are consistent with those of Gunstone (1988). There is a persistent alternative conceptions that force is related to speed and, according to this notion, direction of force is indicated by direction of speed, and presence of force is indicated by presence of speed. But instead of using the word ‘force’ it should be replaced by ‘momentum’to change the persistent alternative conceptions of the students.

For the concept of energy, high school and college students mentioned more physical concepts than did elementary students when asked for associations, descriptions, and examples. Elementary students’ responses were more experiential and less abstract or conceptual. Equivalent concepts in the local dialect may play an additional role in alternative conceptions particularly at the elementary level. Data show that the distinction between the concepts of energy and force is easier taught and understood than the finer distinction between the concepts of energy and power.

If energy is little understood, conservation of energy is even less understood. Data obtained from the question items in the study show that the property of being frictionless is difficult to grasp even by college students and may further complicate understanding of the concept of conservation of energy. Among the small of students studied here, the overall pattern emerging is that many alternative conceptions about force and energy persist up to the college level.

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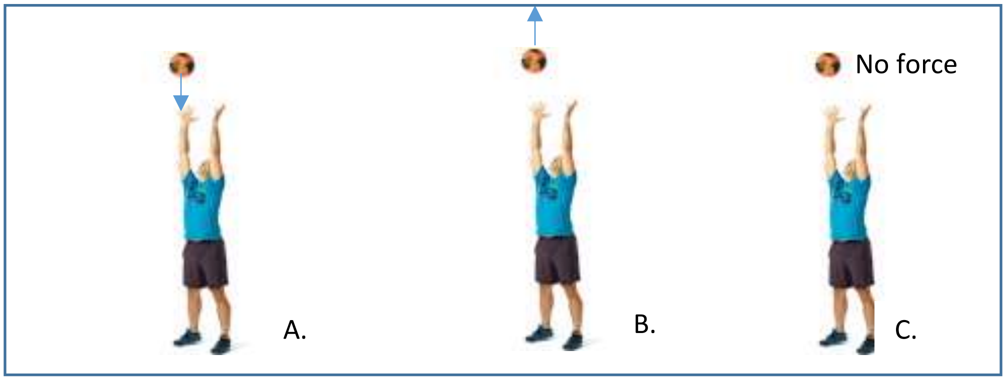
Appendix A

Question 1 – 3

A person throws a ball straight up into the air just a small way.
Questions 1 – 3 are about the *total force* on the ball.

Q.1. *If the ball is on the way up*, then the *force* on the ball is shown by which arrow?



a. Answer: __________ (write A, B, and C in the space)
b. Why did you choose this answer? (please write your reasons)

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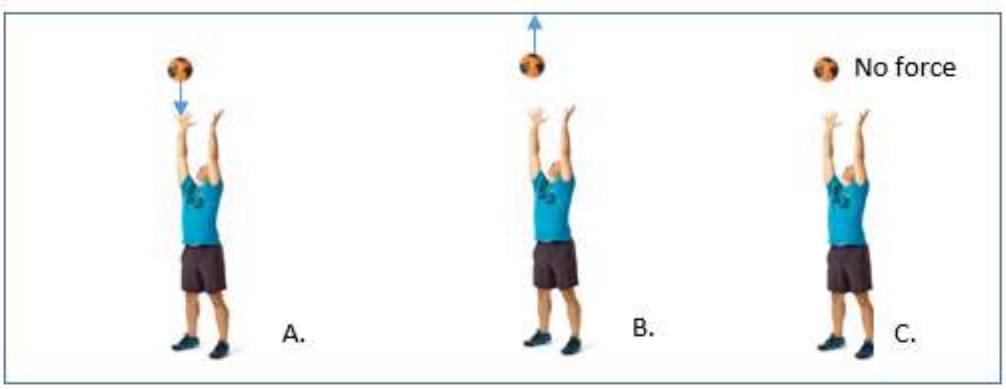
Q.2. *If the ball is just at the top of its flight*, then the *force* on the ball is shown by which arrow?



a. Answer: _________ (write A, B, and C in the space)
b. Why did you choose this answer? ____
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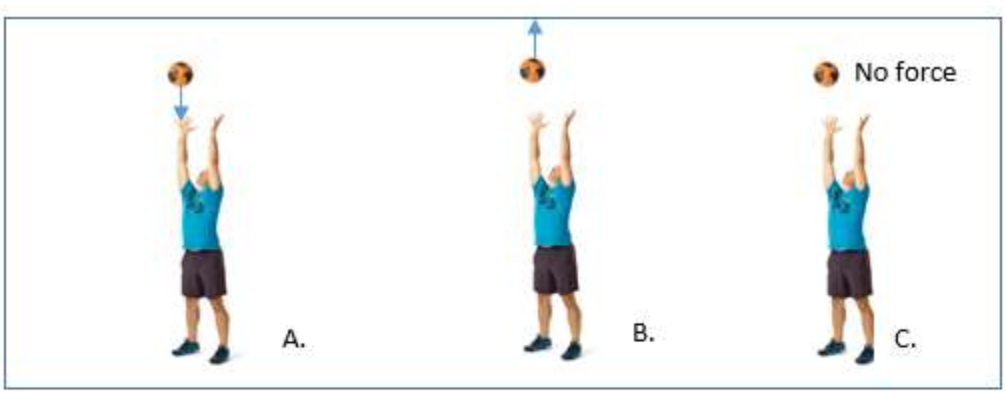
Q.3. *If the ball is on the way down*, then the *force* on the ball is shown by which arrows?



a. Answer: __________ (write A, B, and C in the space)
b. Why did you choose this answer? ______________________________________
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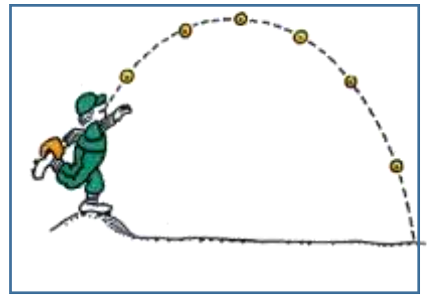
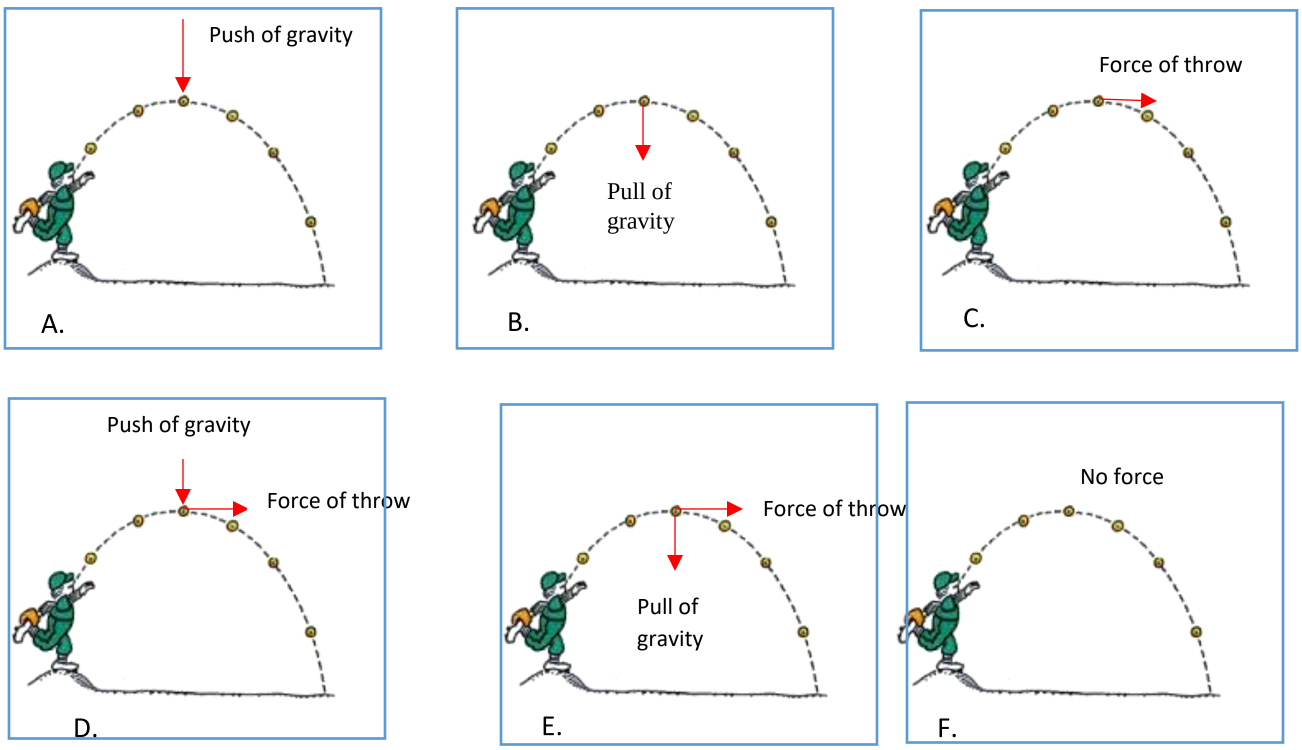
Questions 4 and 5

The person now throws the ball to someone else. This drawing shows the path the ball travels along. Questions 4 and 5 are about *all the forces* on the ball.



Q.4. *When the ball is at its highest point*, which of the drawings below best shows all the forces on the ball?



a. Answer:______________

b. Why did you choose this answer? ____
____
____
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____

c. Are there any other forces on the ball which are not shown in the diagrams? __________ (yes or no). If you answered yes, please describe the force or forces.
____
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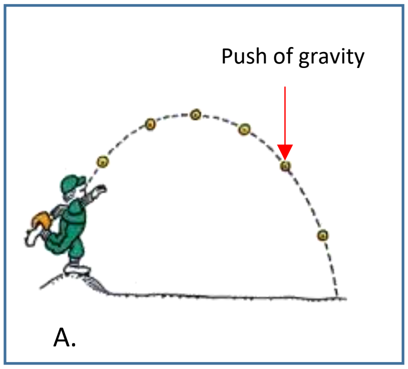
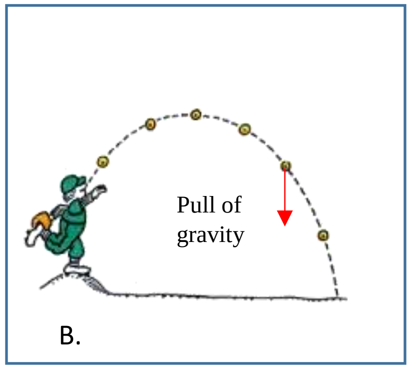
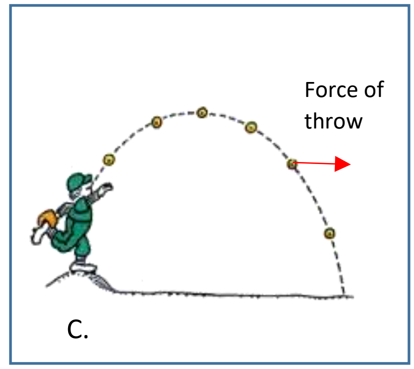
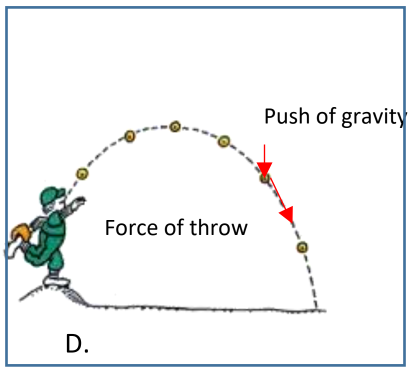
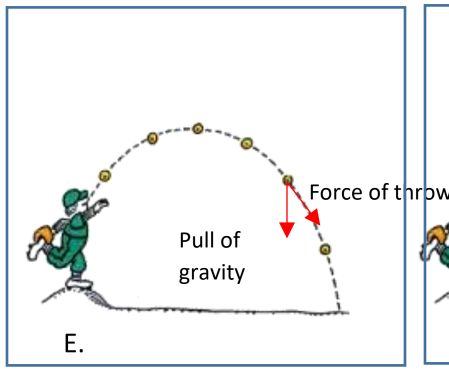
Q.5. *When the ball is on the way down again,* which of the drawings below best shows all the forces on the ball?

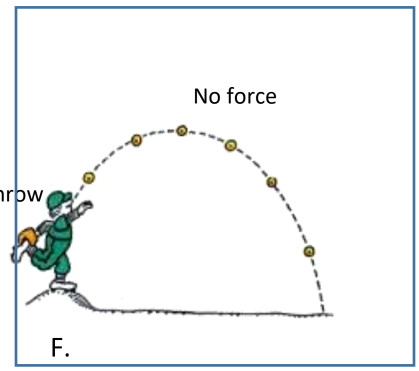












a. Answer: ____________
b. Why did you choose this answer? ____
____
____
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____
c. Are there any other forces on the ball which are not shown in the diagrams? __________ (yes or no). If you answered yes, please describe the force or forces.

____
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____

Question 6

A person is riding a bicycle. The person is not using the breaks or pedals and is slowing down.

Is there a force on the bicycle?

A. Yes
B. No
    a. Answer: ___________
    b. Please explain your answer:

____
____
____
____
____
____

Question 7 – 11

These questions are about whether there would be gravity in different places.

Q.7. Look at picture 1. Is there any *gravity* when you are standing on the earth?

Picture 1. Standing on the earth

A. Yes
B. No
    a. Answer: ___________
    b. Please explain your answer:

____
____
____
____
____
____

Q.8. Look at picture 2. If someone falls from an aeroplane, is there any *gravity?*

Picture 2. Falling from an aeroplane

A. Yes, about the same as on the ground
B. Yes, but much less than on the ground
C. Yes, but much more than on the ground
D. No, there is no gravity
   a. Answer: ___________
   b. Please explain your answer:
   ____
   ____
   ____
   ____
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   ____

Q.9. Look at picture 3. If someone is standing on the moon, is there any *gravity?*

Picture 3. Standing on the moon

A. Yes, but much more than on the earth
B. Yes, about the same as on the earth
C. Yes, but much less than on the earth
D. No, there is no gravity
   a. Answer: ___________
   b. Please explain your answer:
   ____
   ____

____
____
____

Q.10. Look at picture 4. The satellite is going around the earth. Is there any gravity up where the spaceman is?

Picture 4. Spaceman near a satellite

A. Yes
B. No
  a. Answer: ___________
  b. Please explain your answer:

____
____
____
____
____
____

Q.11. Look at picture 5. Is there any gravity when the person is swimming under water?

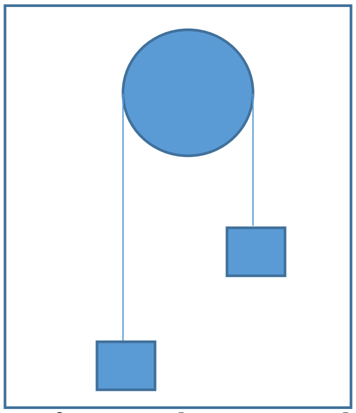
Picture 5. Swimming underwater

A. Yes
B. No
C. Depends on whether the person is going up or down.
  a. Answer: ___________
  b. Please explain your answer:

____
____
____
____

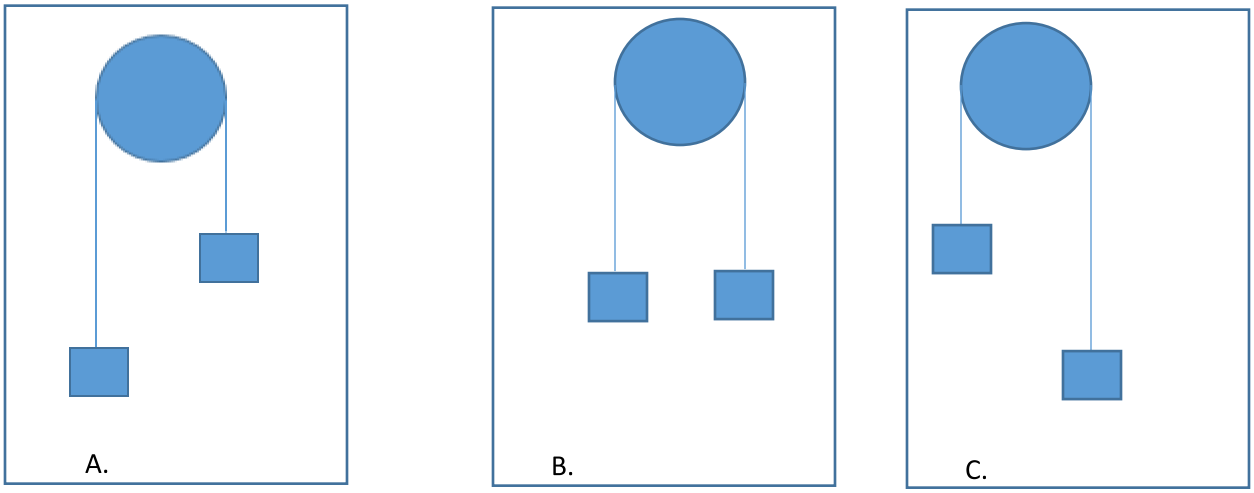
____
____

Question 12



Two equal blocks are linked by a piece of string. The string is placed over a pulley, so the blocks are at rest in the positions shown in the picture above.

When we look at the blocks one minute later, which of the three pictures below best shows the positions of the blocks now?



a. Answer: ____________
b. Why did you choose this answer? ____

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Appendix B

Questionnaire on Energy, Work, Power, Force

(IPN- Institute for Science Education at the University of Kiel-Physics Education Department, R. Duit, 1981)

School: ________________________________ Age: ___ Date: ____________

Your last name: _________________________ First Name: _____________

The concepts "energy", "work", "power", and "force" play a major role in physics and therefore in physics instruction, too. In the first part of this questionnaire we would like to find out something about your ideas of these concepts. All questions in this part refer to the four concepts "energy", "work", "power", and "force" as they are used in physics instruction and not as they are used in everyday language.

If you have not yet heard anything about these concepts in your physics class, give the ideas you have formed about them on your own.

---

1. When you hear or read a word, you usually associate other words which have something to do with the word you heard or read about. The following task concerns such associations. Seven physical concepts will be named (e.g. written at the blackboard) one after another. You have about 30 seconds for every concept in which to write down the words which come to your mind.
   a. ____
   ____
   ____
   _____
   b. ____
   ____
   ____
   ____
   c. ____
   ____
   ____
   ____
   d. ____
   ____

____

e. ____

f. ____

g. ____

2. It is not so easy to describe in a few words the meaning of the physical concepts energy, work, power or force. Please try anyway to find another description for the meaning of these concepts in physics.

   If you have not yet heard anything about these concepts in your physics class, give a description of the ideas you have formed about them on your own.

   Description for ENERGY:

   ____

   Description for WORK:

   ____

   Description for POWER:

   ____

   Description for FORCE:

____

3. Perhaps in task 2 you have had some problems in describing your ideas and notions about the four concepts. Maybe it is easier for you to give an example for every concept. "Peter stretches a rubber band" may for instance serve as an example of work, and "A new battery lights up a lamp" as an example of energy.

   Please write down your own examples for "energy", "work", "power", and "force".

Example for ENERGY:

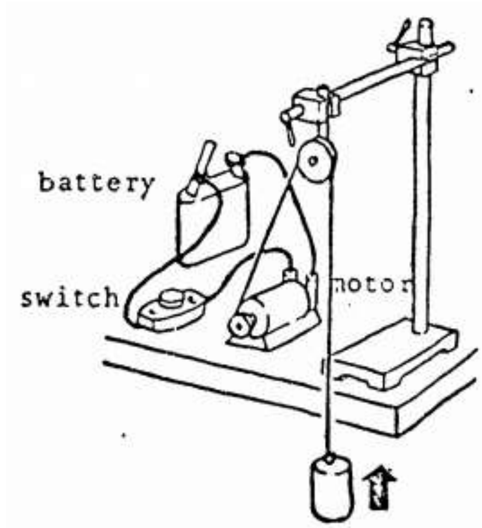
Example for WORK:

Example for POWER:

Example for FORCE:

4. The drawing shows a “toy crane”. When the switch is closed, the “crane” lifts a weight. Please describe this process by using each of the following four concepts at least once: ENERGY, WORK, POWER and FORCE.

   If you have heard something about these concepts in your physics class take the physical meaning. If you have not yet heard anything about these concepts use the ideas you have formed about them on your own.



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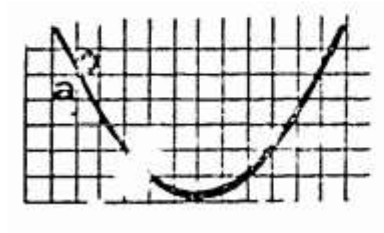
ATTENTION: In the following tasks 5 and 6, a ball follows a curved path or takes its course over slopes of various shapes. As the friction is very small in these motions we want to pretend that *there is no friction* at all. Friction is, of course, unavoidable in all motions in our surroundings, e.g., friction with air, friction during rolling, or friction in the axles of a car.

In the following two tasks we will neglect all kinds of friction. *We want to pretend that the ball is not decelerated by friction* of any kind.

5. In the three graphs, a ball follows a curved path. The path is released at the marked spot and then rolls with no drive of its own. In all the experiments we want to pretend that there is no friction.

5a. Mark with (1) the spot you think the ball will reach before it begins to roll back. Give a short reason for your answer.

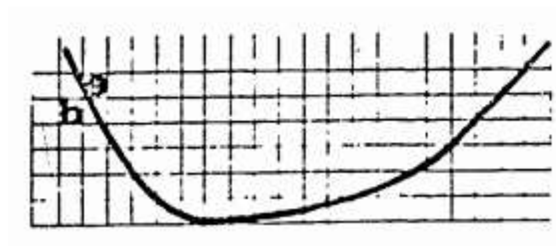


Reason:____

The ball does not remain at the spot you marked with (1). It rolls back along the curved path and reaches a spot at the other side of the path. Mark this spot with a (2). Give a short reason for your answer here too.

Reason:____

5b. Once again mark with (1) the spot you think the ball will reach before it begins to roll back. Give a short reason for your answer.

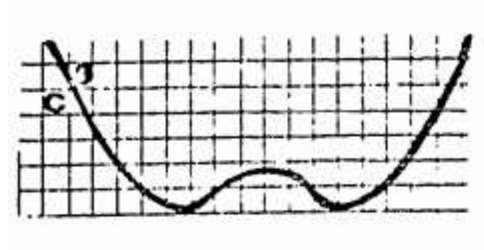


Reason:____

As in 5a mark with a (2) the spot which the ball will reach when it rolls back from spot (1). Please give reason.

Reason:____

5c. Mark *only with (1)* the spot which the ball will reach before it begins to roll back. Please explain.



Reason:____

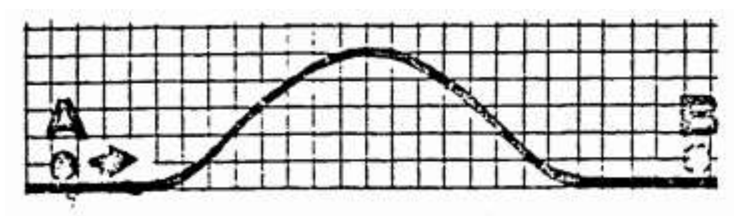
6. In this task our ball takes it course over slopes of various shapes. The speed of the ball at spot A is always so great that it can go over the slope.

   Again, the ball rolls *without any drive of its own* and we shall pretend that there is *no friction.*

   Compare the speed of the ball behind the slope (at spot B) and in front of the slope (at spot A).

   Put a cross next to the correct answer and give a reason.

   6a.



The speed of the ball at spot B is ….

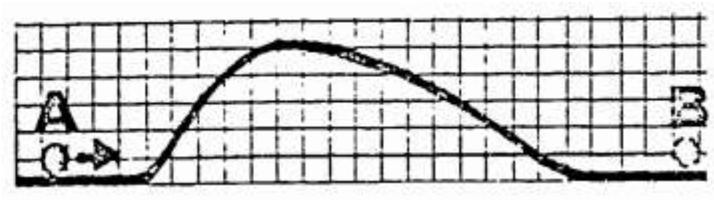
Greater than ( )

Less than ( )

The same as ( ) … at spot A.

Reason:____

6b.



The speed of the ball at spot B is ….

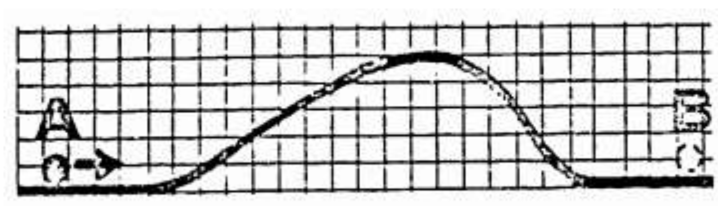
Greater than ( )

Less than ( )

The same as ( ) … at spot A.

Reason:____

6c.



The speed of the ball at spot B is ….

Greater than ( )

Less than ( )

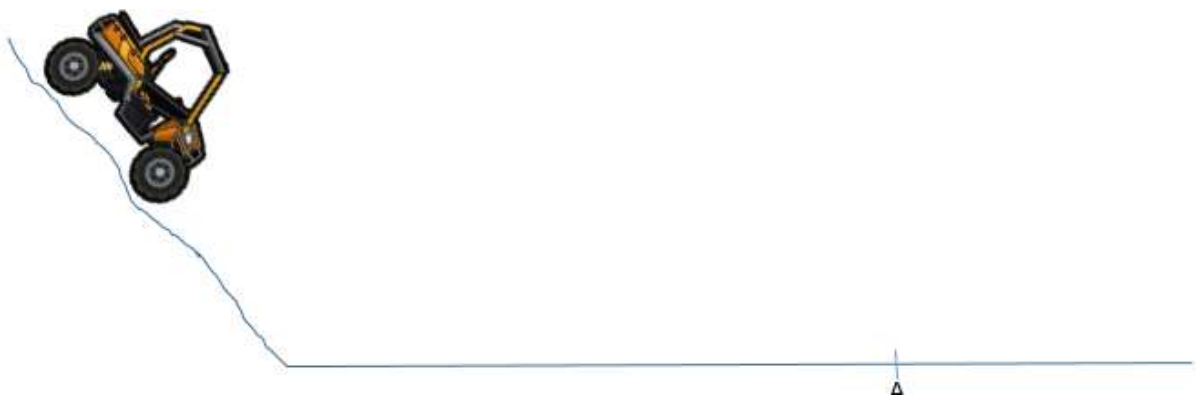
The same as ( ) … at spot A.

Reason:____

7. The last two tasks were concerned with the motion of balls without any friction. We will now turn over to motion with friction.

ATTENTION: In this task you have to take friction into consideration.

We don't pretend any more that there is no friction.



In the *first trial a car is loaded only with the driver.* It starts rolling down a hill *without any drive by the motor* and comes to rest at point A of the horizontal path.

In the *second trial* the car is loaded with 5 persons. It starts rolling at the same place as in the first trial and rolls down the hill without any drive by the motor, too. Where does the come to rest in the second trial?

Please mark this point with a cross (X).

Please explain your answer.

____

That is the end of the questionnaire.

Thank you very much for answering our questions