GENDER DIFFERENCES IN STUDENTS' IDEAS ABOUT NEWTON'S LAWS OF MOTION

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Introduction

Research in Science education in the 1970s and 1980s (Driver *et al*, 1994,1985) led to the realisation that students hold other ideas about scientific phenomena than the correct scientific conceptions. Researchers focused on a range of topic areas in science. In Physics, such areas included students' ideas in optics (Goldberg & McDermot, 1986); electricity (Shipstone, 1984, 1984a); heat (Erickson & Tiberghein, 1985); to motion (Slojberg & Lie, 1981) among other topics. Research has been so extensive that whole reviews and lists of references on these ideas were published. Publications by Driver *et al.* (1994, 1985) and Pfundt and Duit (1994) are examples of such reviews.

Students have been found to hold numerous alternative frameworks (Driver & Easley, 1978) in the topic of Newton's Laws of Motion. The ideas identified were various and reflect a wide range of reasoning held by students. Alternative frameworks about Newton's Laws of Motion can be grouped as ideas about natural motion; nature of force; interaction between forces; and gravity. In considering natural motion, students have problems in relating velocity, distance and time (Cross & Mehegan, 1989). They hold misperceptions of the path followed by projectiles (McCloskey, 1983) and consider the rest position as natural motion. The action of a force is believed to be that which makes an object move (Driver, 1984). With respect to the nature of force, students were found to often attribute affective properties to forces (Watts, 1983), to think that forces only have to do with living things (Gunstone & Watts, 1985), or involve muscular effort (Osborne, 1985; Gilbert *et al*, 1982). In the case of the action of forces, students often believe forces to be only the property of single objects (Brown, 1989), to be innate or acquired (Osborne, 1985; Watts, 1983), do not allow things to happen (Bliss *et al*, 1989; Watts, 1983), are always large in magnitude (Watts, 1983), and need a medium to act (Gilbert *et al*, 1982; Watts, 1983, 1982).Other alternative frameworks with respect to the properties of forces include difficulty in identifying their point of action (Terry *et al*, 1985), and confusion with other physical quantities such as energy, power and movement (Gamble, 1989; Viennot, 1979).

Problems have also been identified in students' reasoning when forces cause motion. Osborne (1985) and Viennot (1979) found that students often believe that a force is acting whenever an object is moving and continues acting as long as it keeps on moving (Driver, 1984; Gunstone & Watts, 1985; Watts, 1983; Watts & Zylbersztejn, 1981). In addition, students commonly think that the faster an object moves, even if at constant velocity, the greater is the force acting on it (Barbetta *et al*, 1984; Driver, 1984; Driver *et al*, 1994; Gunstone & Watts, 1985; Viennot, 1979). Finally, other ideas include the need for a force to act in the direction of motion (Galili & Varda, 1992; Gamble, 1989) and that its magnitude decreases with time (Gilbert *et al*, 1982).

A whole series of alternative frameworks have also been identified about the concept of gravity but these will not be considered here as they were not included in the study.

Science educators have gone beyond identifying or 'stamp collecting' children's ideas by putting forward arguments as to what causes children to use such reasoning. A number of possible factors were identified and arguments in favour of their influence were put forward. Some researchers identified the influence of personal experience in everyday life (Claxton, 1993; Osborne *et al*, 1990; Russel, 1993, Solomon, 1983). Others emphasised the influence of language and culture in reasoning patterns (Claxton, 1993; Russel, 1993). Students' level of cognitive development was also considered (Monk, 1991, 1990).

Aim of research

A common feature of the causes for alternative frameworks put forward by science educators is that they often tend more to substantiated their claims through arguments rather than through first hand data. There is very little research reported in literature that actually probes factors that influence reasoning or patterns of ideas held across different groups, be they across gender, culture or any other group.

This is what this research actually aims to do. Although this paper focuses mainly on gender differences, the results reported form part of a wider doctorate research that aimed to:

- first identify students' ideas held by Maltese secondary level students on the topic of Newton's Laws of Motion;

- then to study whether such ideas identified show differences across gender, school, cognitive development and cognitive style (Verbaliser-Imager and Analytic-wholist dimensions as used by Riding, 1991);

- and finally, to develop a constructivist teaching scheme in order to help students understand Newton's Laws of Motion better.

This paper reports gender differences identified in the types of ideas held by Maltese secondary level students.

Local Context

This research was carried out in Maltese grammar type secondary schools. Compulsory education in Malta spans over the age range of 5-16. It involves six years of primary education followed by another five years of secondary education. At the end of primary education, most students sit for a competitive eleven plus examination in English, Mathematics, Maltese, Religion and Social Studies.

All students proceed to secondary education. Those who pass the eleven plus examination attend grammar types schools called Junior Lyceums. About half of the children sitting for the entrance examination pass. Educators usually assume that the upper 50% of the student cohort attend these schools. However, one must be careful with such an assumption since about 30% of Maltese children attend Church or

Independent (private) schools (NSO, 2001) with the boys' secondary Church schools having a very competitive entrance examination.

That half of the student cohort who 'do not make the grade' attend area secondary schools similar to secondary modern type schools in England after the 1944 Education Act. They follow the same syllabus as students attending Junior Lyceum Schools. All state secondary schools in Malta are single sex.

It is compulsory for all secondary students to study one science, this being Physics in state schools. At the end of secondary education, students sit for the national school-leaving examinations, the Secondary Education Certificate (SEC) run by the MATSEC Examination Board at the University of Malta.

The study reported in this paper was carried out in Junior Lyceum schools.

Methodology

Students' ideas on the topic of Newton's Laws of Motion were probed through the use of a questionnaire. Following a review of the main alternative frameworks identified in literature and analysis of the types of items used in other research projects (Watts, 1985; Welford *et al,* 1986 among others) a number of items were collated into a questionnaire and piloted.

Table 1. Source of Questionnaire items and alternative frameworks targeted

Item	Source	Alternative Framework Targeted
1	APU (Assessment Performance Unit)	meaning of forces, complexity of concept of forces held
2	Gilbert, Watts & Osborne, (1992)	confusion of meaning of force in physics with that of everyday language, properties of a force
3	APU (Assessment Performance Unit)	resultant force is necessary to maintain uniform motion
4	Adaptation of Gunstone & Watts (1985)	resultant force must act in the direction of motion
5	Millar & Kragh (1994)	perception of motion
6	APU + Part from Watts	Newton's third law pairs of (a) objects in contact (b) objects at a distance from each other
7	Several Sources: Adaptation from APU	resultant force must act in the direction of motion
8	APU	Newton's third law pairs and point of action of forces
9	Millar & Kragh (1992)	identification of frames of reference in an unfamiliar situation
10	McCloskey *et al.* (1985)	identification of frames of reference in a familiar situation
11	Terry, Jones & Hurford (1985)	Newton's third law - action between two masses of different sizes.
12	the researcher	no resultant force acts when an object is stationary, force causes motion
13	Millar & Kragh (1994)	Newton' Third Law in dynamic situation, large moving object exerts a larger force.

The questionnaire consisted of 13 items (see Appendix). Each item targeted one or more alternative frameworks. The ideas probed in each question and its source are given in table 1. The main pattern of structure of the questions consisted of a multiple-choice closed-ended response in the first part followed by an open-ended part that requested students to explain their reasoning for selecting the particular multiple-choice option.

The first item served to set the context. The rest of the questionnaire was divided into three main sections. The areas covered in each section included:

- the meaning of Force in Physics;
- Newton's First Law and Second Law and their implications;
- the action of force in Newton's Third Law.

Students were asked to complete the questionnaire about four weeks after covering the topic motion at school. Consultation with the teachers involved allowed good timing to be possible. The questionnaire was then administered one classroom at a time during a free lesson. Students took about 45 minutes to complete the questionnaire, the time of one lesson.

Sample

The questionnaire was administered to all fourth Form (fourth year) students in five Junior Lyceum schools. All students in each school, rather than a sample from each school were included since schools streamed students according to academic ability and consequently it was not possible to obtain a representative sample of Junior Lyceum students. Taking the whole student population in the year solved the sampling problem and allowed the analysis of students' ideas across ability within this type of schools.

A total of five Junior Lyceum schools, three boys' and two girls', were chosen out of a total of 8 schools. Since schools have different catchment areas, care was taken to choose schools representing a good geographic distribution. Three boys' schools were chosen to ensure a better balance in number between the two sexes. A total of 790 students completed the questionnaire, 338 of which were boys and 450 girls.

Results

Analysis of students' responses was done in two different ways. In the first approach, a measure of students' overall performance was worked out. This was done by first categorising students' responses according to levels of understanding of Newton's Laws of Motion and assigning to them marks, with 1 as lowest and 5, in many cases, as highest. An overall value obtained by each student was then worked out. Details of the marking scheme are provided in Gatt (2002). Three sets of values were worked out for level of understanding: Newton's First and Second Laws; Newton's Third Law; and an overall value for all three laws. In the second approach, students' responses were analysed in more detail with all items considered separately and χ^2 tests carried out across gender.

Overall Gender differences

A t-test carried out across the three main measures gave a gender difference for the overall measure and for the first and second law. The effect size is in each case, however, low to moderate. In both cases, the trend is always for girls doing better than boys. Such a result is in line with the same students' Physics annual examination results which showed that girls outperformed boys (Gatt, 2003, in press).

Table 2: t-tests for marking schemes across gender

Section	Mean		t-value	df	sig.	Effect Size
	Boys	Girls				
1st & 2nd Law	51.2	53.66	18.052	787	<0.001	0.16
Overall	67.88	73.90	4.058	777	<0.001	0.28

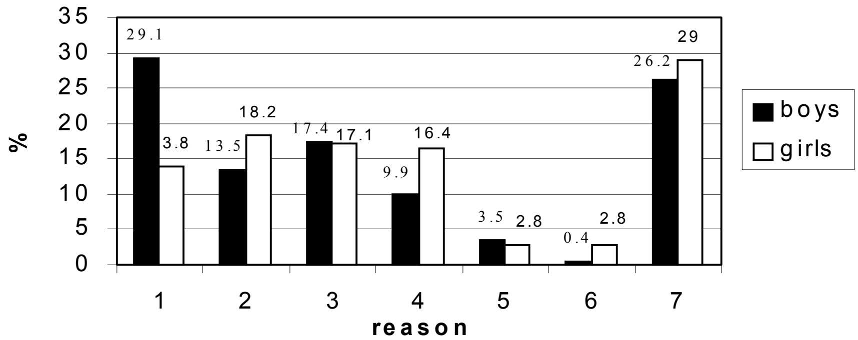
Differences in Alternative Frameworks

Further insight can be obtained by considering the individual responses. Gender differences were found to be statistically significant ($p<0.001$) in many of the items of the questionnaire. Analyses of these differences reflect a number of trends.

A gender difference in the preference for different ideas was obtained. Boys performed better than girls in their understanding of the meaning of force and implications of the First and Second Laws of Motion when considering practical situations. Girls, on the other hand, have done better than boys in situations concerning Newton's Third Law.

Meaning of Force

More boys than girls gave a correct answer when asked if a force is acting in a situation as in item 2. This amounted to 10% more boys (74.26%) than girls choosing the correct option (χ^2=8.086, p=0.001).



(1) No force is present as there is no contact
(2) Force given an everyday language interpretation
(3) No force is present as there is no motion
(4) Focuses on forces present on one of the persons
(5) Simply states answer
(6) Mentions Work/ energy
(7) Relates force to push

Figure 1: Distribution of reasons given to item 2 across gender

Analysis of the reasons given, however, shows that more girls actually gave the correct reason. Boys chose the correct option using the wrong reasoning. About 15% more boys than girls believe that there must be contact between two objects in order for a force to act (reason 1). More girls, on the other hand, tended to either give a language interpretation or else to focus on one of the persons.

Gender differences were obtained when students were asked about the action of a resultant force (item 3). Boys (39.26%) performed better than girls (18.8%) in choosing the correct option to the situation presented (χ^2=37.61, p<0.001). This item required the understanding that there must be no net resultant force for an object to continue moving forward at uniform velocity. Boys were consistently better in that a greater percentage also gave the correct reason for their choice (χ^2=83.191, p< 0.001). This difference is, in fact, significant with about 30% more boys than girls giving the correct reason.

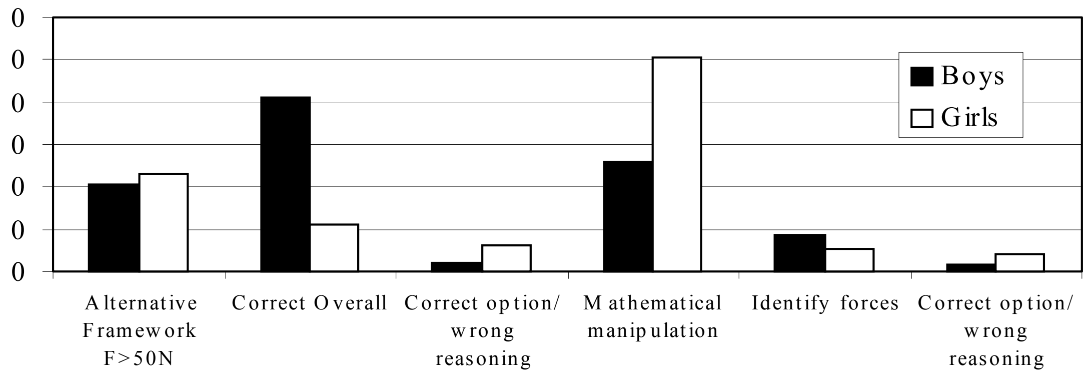


Figure 2: Percentage of categories of reasoning across gender

The reasons also show the limited view girls took when tackling the situation. Practically half of the girls resorted to a mathematical manipulation, adding up the values given. Otherwise the same percentage of boys to girls hold the alternative idea that a resultant force must act in the direction of travel of the object**.**

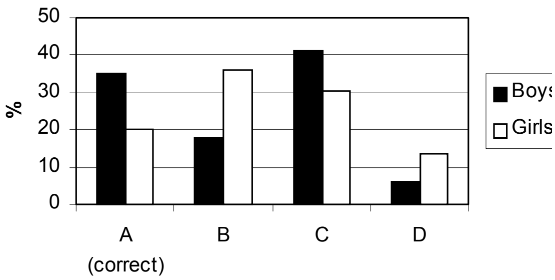
Frames of reference

Boys also show a better understanding when considering frames of reference with a greater percentage of boys getting items 9 and 10 correct, and in also being able to give the correct reason in question 10 when stating that the bomb has the same velocity as the plane.

Table 3: Distribution of correct/wrong answers to items 9 & 10.

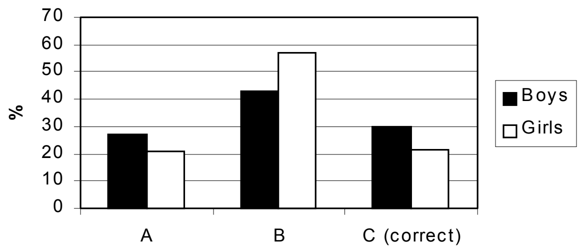
	Boys		Girls	
	No.	**%**	**No.**	**%**
Q9 Correct Option	107	35.0	86	20.0
Wrong Option	199	65	343	80
	χ^2=20.535 p<0.001, N=735			
Q10 Correct Option	88	30.1	90	21.6
Wrong Option	204	69.9	326	78.4
	χ^2=6.59, p=0.01, N=708			
Q9 Correct Reason	58	26.7	47	3.2
Wrong Reason	159	73.3	308	86.8
	χ^2=16.35 p<0.001, N=572			

Gender differences are also obtained in the distribution of the options chosen. In both items, girls prefer vertical motion (option B) whereas boys opt for the trajectory possibilities. Boys show a greater familiarity with the situation. Bombs and planes are usually associated more with boys and so this may have put them at an advantage over girls.



χ^2=103.31 p<0.001, N=572

item 9



χ^2=14.408 p=0.001 N=708

item 10

Figure 3: Distribution of options for items 9 & 10 respectively across gender

The girls' preference for vertical motion becomes more evident when considering the reasons given by students for their choices. Girls tended to focus more on either the action of gravity pulling the bomb or ball down to the ground, or else resorted simply to just describing the path taken by the ball, stating that '*it falls straight downwards'*. The latter type of reasoning was more accentuated in item 10.

Table 4: Distribution of Reasons given for items 9 and 10 across gender

Reason	Item 9		Item 10	
	Boys No. (%)	Girls No. (%)	Boys No. (%)	Girls No. (%)
Ball released not thrown	-	-	11(5.9)	16(5.1)
Plane/man has velocity, bomb/ball no	70(32.3)	113(31.8)	36(19.3)	28(8.9)
Bomb/ball has same velocity as man/plane*	58(26.7)	47(13.2)	51(27.3)	61(19.3)
Gravity	29(13.4)	71(20.0)	26(13.9)	66(20.9)
Refers to motion of bomb/ball	28(12.9)	69(19.4)	35(18.7)	107(33.9)
Mentions other physical quantities	25(11.5)	48(13.5))	17(9.1)	10(3.2)
Ball thrown down	-	-	11(5.9)	29(8.9)
Gravity and air resistance	7(3.2)	7(2.0)	-	-

Item 9 : χ^2=21.426, p=0.001, N=572)   Item 10:χ^2=35.172, p<0.001 N=503
*** correct reason**

These two items reflect boys' better acquaintance with trajectory motion and the path followed by projectiles. Girls seem to take a straightforward approach to the situation, and so simplify it to vertical motion under gravity. It may also be that girls restrict thinking to that physics covered in class and this situation was closest to vertical motion. Boys, on the other hand, do not appear to be limited by school physics knowledge and are more flexible, even if not accurate in applying knowledge to new situations, and often resort to personal experience and beliefs.

Forces acting on moving objects

A gender difference was obtained when it came to identify the forces acting on an object thrown either vertically (item 4) or trajectory (item 7). Not only, when gender differences were significant, did boys perform better in giving correct answers, but also show a greater insight of the situations presented when giving reasons. The trend appears to be the same as that outlined so far.

Table 5: Distribution of correct/wrong answers to items 4 & 7(c)

	Boys		Girls	
	No.	%	No.	%
4(c)Correct reason*	118	47.7	128	33.3
4(c)Wrong reason	131	52.6	260	66.6
7(c)Correct option**	75	24.5	152	35.5
7(c)Wrong option	231	75.5	276	64.5

***χ^2=13.267, p<0.001,   **χ^2=10.115, p=0.001**

A gender difference in the percentage correct answer was obtained only in part (c) of both items 4 and 7. However, whereas more boys (50%) than girls (33%) chose the correct option in item 4, the trend is reversed in item 7 (24.5% for boys against 35.5% for girls' correct choice).

This difference can be explained in terms of the girls' preference to translate all motion, even if trajectory, to vertical motion. Since the force in question in such situations is gravity, which acts directly downwards, girls may have chosen the correct option due to translating the ball's motion downwards under the action of gravity. On the other hand, boys may have used the alternative framework of a force in the direction of motion. This is further substantiated in considering the separate options chosen. In part (b), more girls chose 'no force' whereas more boys used the same thinking consistently by going for the force acting in the direction of motion.

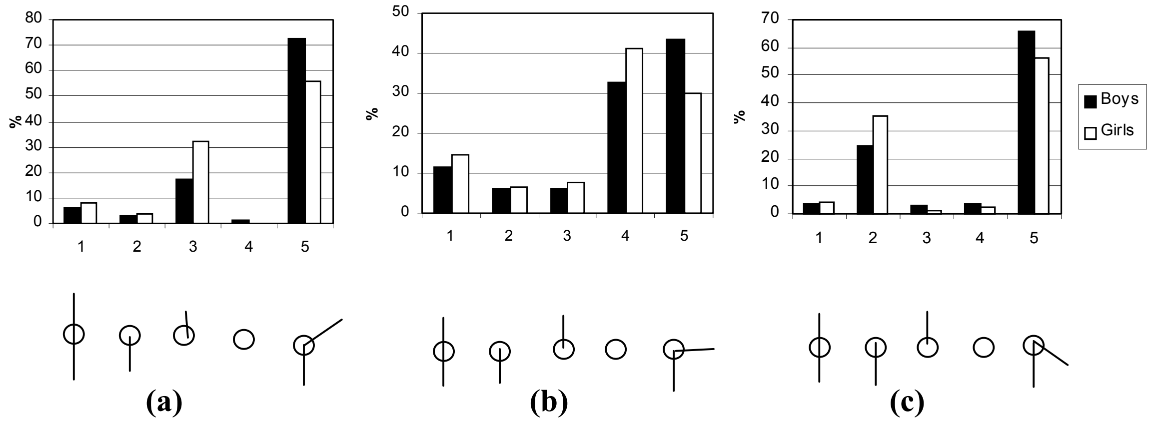


Figure 4: Percentage frequency of options chosen for parts (a), (b) & (c) in item 7

Students show consistency in stating their reasons for choosing particular options. Gender differences were obtained for reasons given to choice of option in parts (a) and (c) of item 4 and in parts (a) and (b) of item 7.

Table 6: Frequency of reasons given to part 4(a) across gender

Reason	**Boys**		**Girls**	
	No.	**%**	**No.**	**%**
Force Given to ball	85	32.6	129	31.9
Force given to ball & gravity	73	28.0	75	18.6
Force in the direction of motion	51	19.5	89	22.0
Mentions Gravity/wt of ball (correct)	18	6.9	19	4.7
Need for larger force upwards	5	1.9	11	2.7
Names the forces present	26	10.0	55	13.6
Refers to the direction of motion	3	1.1	20	6.4
TOTAL	**261**	**100**	**398**	**100**

χ^2=20.486, p=0.002

In considering the upward path in either case, more boys in item 4 mentioned the presence of gravity together with that in the direction of motion of the ball. This reflects how scientific concepts met in school are assimilated into the original schemes rather than promoting modification (Bliss *et al,* 1989).

Table 7: Frequency of reasons given to part 7(a) across gender

Reason given	**Boys**		**Girls**	
	No.	**%**	**No.**	**%**
Gravity (correct)	12	4.6	13	3.2
Force in the direction of motion	66	25.3	128	32.1
Force in the direction of motion & gravity	119	45.6	122	30.7
Focuses on the ball	9	3.4	32	8
Mentions other physical quantities	14	5.4	8	2.0
Refers to direction of motion	41	15.7	96	24.0
TOTAL	**261**	**100**	**399**	**100**

χ^2=24.71, p<0.001

A similar trend of thought is identified in 7(a), where more girls, again, mention the force in the direction of motion of the ball. Similarly, more boys include the action of gravity with the force in the direction of travel of the ball. As in item 4, more girls also tended to just mention the direction taken or focused on the ball.

Gender differences were also present in item 7(b) when considering the ball at the highest position. The main difference is that about half of the girls believed that no forces are present on the ball. Boys did not show such a great preference to one type of reasoning but tended to refer to the direction of travel of the ball, that it is moving. Once again, girls tended to oversimplify the situation in consideration.

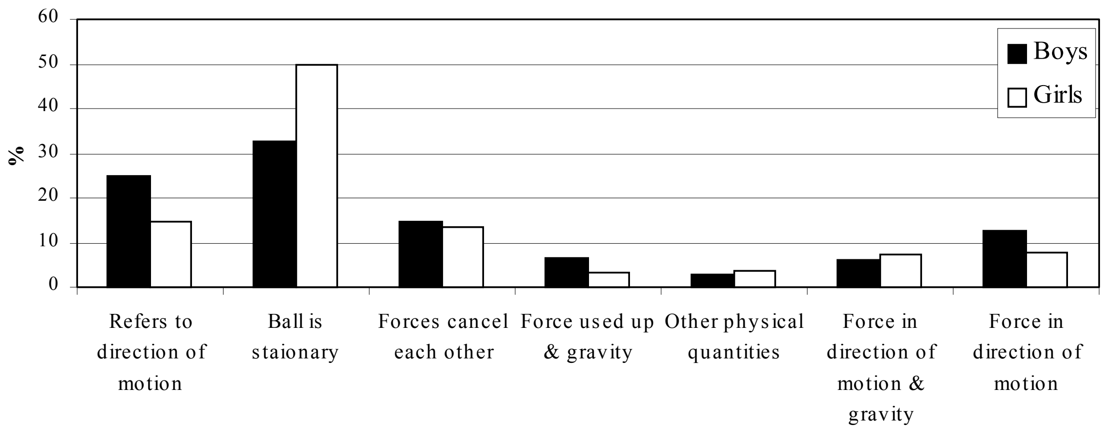


Figure 5: Percentage distribution of reasons given to part 7(b) across gender.

In considering the ball's path towards the ground, differences were obtained only for item 4 (Table 8). A 15% difference is present for boys mentioning gravity. Girls, on the other hand, show a greater frequency in referring to the direction of travel of the ball (+4%), in considering the need for a greater force downward (+5%), and in including air resistance with gravity (+4.5%). The latter option cannot be considered as completely wrong even though the students were told to neglect air resistance.

Table 8: Frequency of Reasons given to part 4(c) across gender

Reason	Boys		Girls	
	No.	**%**	**No.**	**%**
Refers to gravity/wt	118	47.8	128	33.0
Refers to the direction of motion	83	33.6	147	37.9
Mention gravity & air resistance	10	4.0	33	8.5
Larger force downwards	13	5.3	39	10.1
Mentions opposing force	12	4.9	20	5.2
Force is used up	2	0.8	8	2.1
No force present	9	3.6	13	3.4
TOTAL (635)	247	100	388	100

(χ^2=19.494,P=0.003, n= 625)

Although gender differences did not emerge in all questionnaire items targeting the first and second law, similar trends have emerged from a number of the responses given. These show that boys tend to fare better when considering practical situations whereas girls appear to stick to their limited physics knowledge reflecting very little effort in trying to apply knowledge learnt in one situation to new contexts.

Newton's Third Law of Motion

A different trend is observed in this section in that girls perform better than boys in many of the cases. This is observed mainly in items 6 and 8, which are similar to examples usually considered during instruction. On the other hand, items 11 and 13, which refer more to practical situations, show boys having a better insight into the forces acting.

Girls are better than boys at identifying the forces acting on an object. This was obtained in the case of item 8. More than twice as many girls than boys drew the forces acting on the book on the table correctly (Table 9). There were also more girls who knew that the forces were the weight and the reaction of the table but drew the forces at the wrong point of action. About half of the boys, on the other hand, drew the weight. In this case, girls have been superior not only in identifying the forces present but also in identifying their correct point of action.

Table 9: Distribution of types of forces drawn for item 8 across gender

Forces Drawn	Boys No. (%)	Girls No. (%)
Weight & other force	23 (10.5)	17 (5.0)
Weight & Reaction (wrong point of action)	45 (20.5)	149 (43.8)
Weight (wrong point of action)	74 (33.8)	53 (15.6)
Weight only (correct point of action)	44 (20.1)	12 (3.5)
Weight, reaction & other force	3 (1.4)	27 (7.9)
Other physical quantities	17 (7.8)	41 (12.1)
Reaction only	8 (3.7)	20 (5.9)
Weight & Reaction (Correct point of action)	5 (2.3)	21 (6.2)
TOTAL	**219 (100)**	**340 (100)**

χ^2=101.075, p<0.001

Girls have done better than boys also in item 6 where they were required to draw Newton's third law pair to the weight of a man standing in part (a), and to a falling object in part (b). Again, more than twice as many girls than boys drew the correct paired force in 6(b).

Table 10: Distribution of Correct/wrong answers across gender for item 6(b).

	Boys		**Girls**	
	No.	**%**	**No.**	**%**
6(b) Correct	11	5.8	42	13.0
Wrong	178	94.2	280	87.0
χ^2=6.685, p=0.01, N=458				

Gender differences are also present in the different types of forces drawn in 6(a). More girls than boys drew the correct force. Twice as many girls also drew the reaction at the ground, which is equal and opposite to the weight, but is not the paired force. Boys, on the other hand, are aware that the paired force must act upwards. They, however, have not identified the correct point of action of this force. It appears that boys tend to be approximate in their retrieval.

Table 11: Distribution of forces drawn across gender for item 6(a)

Forces Drawn	**Boys** **No. %**	**Girls** **No. %**
Reaction at Ground	17 (9.7)	57 (18.9)
Gravity	13 (7.4)	6 (2.0)
Force sideways	12 (6.9)	27 (9.0)
Force Upwards	94 (53.7)	85 (28.2)
Force downwards	25 (14.3)	64 (21.3)
Mentions other quantities	2 (1.1)	24 (8.0)
Correct Pair	12 (6.9)	38 (12.6)
TOTAL	**175 (100.0)**	**301 (100.0)**

χ^2=49.783, p<0.001, N=476

More girls are also aware of the Newton's paired forces in the case of one object on top of another. This is observed in item 11 (χ^2=18.04, p<0.001, N=739) where more girls than boys stated that the object at the bottom also exerts a force on the one on top of it. This difference amounts to about 15%.

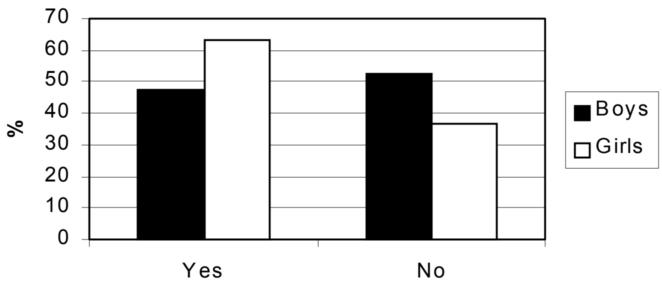


Figure 6: Distribution of Yes/No answers across gender for item 11 2nd part.

A different trend is, however, obtained when considering the students' comments about the size of forces where a greater percentage of boys gave the correct answer. Conclusions should be drawn in the light that only those who thought that the object below exerted a force had to answer this part. This implies that rather than more boys knowing Newton's third law better, that from those who believe that two forces are acting, more boys understand Newton's third law well. Girls tend to be influenced by the size of the objects involved.

Table 12: Distribution of ideas held about size of forces in item 11 across gender

	Boys No. %	Girls No. %
Force exerted by A is greater than that exerted by B	78 (53.4)	143(53.8)
Just names the forces acting	12 (8.2)	3 (1.1)
The two forces are equal	52 (35.6)	82 (30.8)
Force due to A is smaller than that due to B	4 (2.7)	38(14.3)
TOTAL	**146 (100)**	**266 (100)**

χ^2=26.013, p<0.001, N=412

Boys reflect a better understanding than girls in item 13. This item considers a practical situation and requires students to apply Newton's third law. Boys are better than girls in knowing that the stationary object being hit exerts a force just the same (χ^2=10.903, p=0.001, N=730). This is consistent with girls' reasoning previously identified where a stationary object is not considered to have force acting on it.

Discussion

The study has shown that Maltese students, similar to other students all over the world, tend to hold alternative frameworks about Newton's Laws of Motion. All the alternative ideas expressed by students, in fact, have already been documented in other types of research in the same topic with students of similar age.

The gender differences obtained in the types of ideas held show girls to do better in examples very close to those tackled during instruction. This was particularly evident in items on Newton's Third Law that were more similar to examples done in class then for items on the First and Second Law. In fact, in the latter case, girls tended to attempt to fit the situations given within a framework learnt during instruction rather than trying to apply their existing knowledge to the new context being considered. This is unusual since girls prefer to learn concepts within their social context rather than as abstract, fragmented and compartmentalized understandings. Levin *et al*

(1987), however, in a research carried out in Danish gymnasia, noted that girls seemed unable to move beyond everyday explanations to seek out the Physics concepts involved. In fact, they report that girls expressed a preference for ‘pure Physics problems’. These researchers argue that girls need to have a thorough understanding of a subject before they move on to the next. When teaching is too fast for them to keep up, girls resort to rote learning with loss of understanding (Levin *et al*, 1987). It could therefore have been the case that girls could remember the answer to items already encountered as they were capable of remembering the answer through tore learning rather than by understanding. Boys, on the other hand, reflect a better understanding of the forces acting in a number of situations. They are also more flexible in applying these learnt concepts to novel situations. The problem lies with their ‘loose’ way of reasoning, showing their limitation in understanding, and many times resulting in a combination of ‘correct’ Physics and alternative frameworks.

Trends obtained in individual items appear at face value to contradict those obtained when a measure for overall understanding was worked out. How is it that although boys appear to demonstrate a higher level of understanding, girls are better performers overall. One should note that although boys tend to reflect better understanding in a number of items, it is sporadic and may not be enough to give a better overall performance than that of girls. It may also be that although more boys than girls understand the concepts better, those boys who do not have a very poor idea, resulting in a lower overall performance for boys. Girls, on the other hand, may perform over a smaller range of understanding.

One must, however, be cautious in drawing conclusions. Gender differences obtained may not necessarily result simply due to the students’ gender. Analysis of the sample’s performance in the same school year’s common annual examination in the core subjects shows that girls in Junior Lyceum schools are academically better than boys in the same type of schools. This can be explained by the creaming off effect that occurs at entry into secondary schools due to a competitive examination for boys’ Church schools (Borg, 1994; Gatt, 2002). In such situation, it is difficult to identify gender as the only factor. The difference in ability between the boys and girls in the sample may have given rise to the difference obtained. Another factor to take into consideration when drawing conclusions is that since the schools in the study are single-sex schools. The differences obtained may have arisen as a result of school differences that are mirrored as gender differences due to being single-sex. For whatever factor, however, differences in reasoning patterns can be said to have been obtained between boys and girls.

Another aspect of alternative frameworks identified is that they were obtained four weeks after formal instruction. It therefore shows that these ideas are persistent and difficult to change. This result supports assertions made by Driver (1985) and Solomon (1983) among many other researchers working in the area of alternative frameworks. It shows that traditional instruction is ineffective in helping students learn the correct scientific concepts. Such findings require that teachers reflect on their methodology. It also provides a strong argument in favour of adapting other methods, among them the constructivist approach, which may provide better learning opportunities than that offered by traditional teaching so far.

Conclusion

Following the intensive research into alternative frameworks carried out in the 70s and 80s, science educators moved straight into taking these ideas into consideration when designing teaching schemes. Little attention was given in research to what factors, be they genetic, psychological of sociological, give rise to alternative frameworks. This study highlights gender differences that result. Likewise, other factors influencing patterns of reasoning may be identified. In such a situation, it may be worth for science education researchers to retrace their path and to reconsider directly the research questions of how do alternative frameworks form and what do they tell us about the way students develop their understanding of scientific concepts.

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NAME : ______________________________ **BOY or GIRL :** ___________

SCHOOL : ___________________________ **CLASS :** _____________

This questionnaire is about the meaning of force in physics and Newton's Laws of Motion.
You should ask if you do not understand a question

---

1. If you were to explain the idea of a **FORCE** to an intelligent 12 year old child, what would you say ?

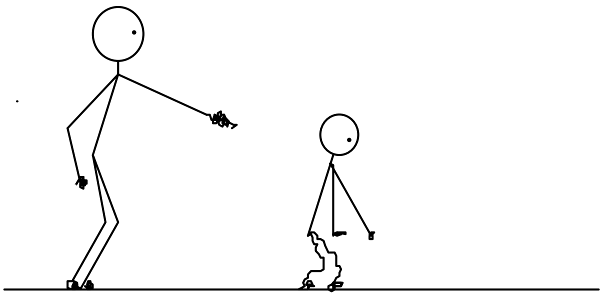
   ____

   ____

   ____

   ____

2. The boy is being told what to do. Is **FORCE** being used ?

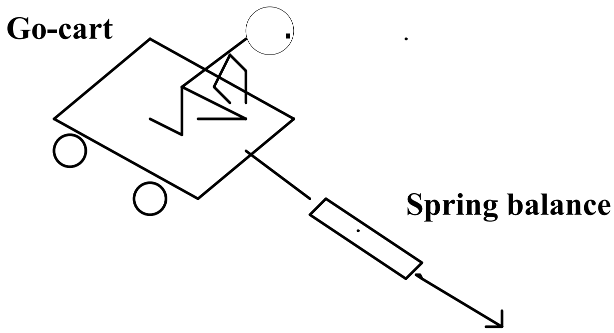


☐ Yes ☐ No

Explain why you think so ____

____

3.



Clive and Derek made a go-cart. Clive pulls at a steady speed along a straight path.
The spring balance shows that he pulls with a force of 50N to do this.
Derek and the go-cart together weigh 400N.

What is the force on the go-cart due to friction and air resistance ?

A ☐ Less that 50N

B ☐ 50N

C ☐ 300N

D ☐ 400N

E ☐ 450N

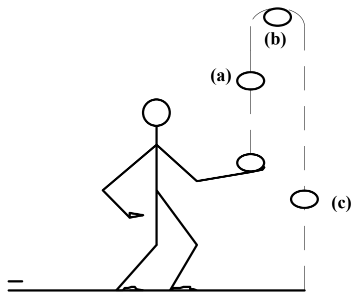
Give a reason for your answer : ______________________________________

____

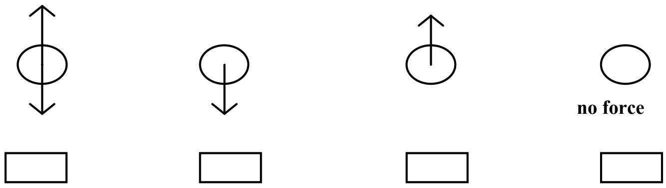
____

____

4. A ball is thrown in air vertically upwards. Neglecting air resistance, which diagram best describes the force(s) acting on the ball when it is :



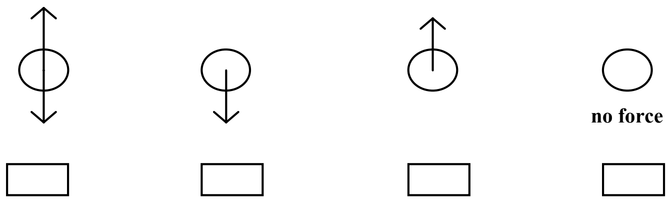
(a) going up



Explain our answer ____

____

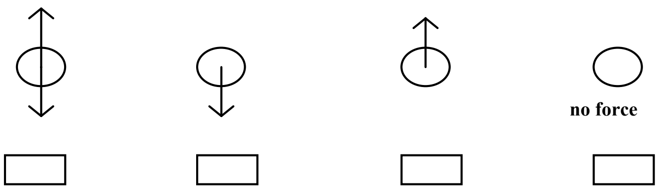
(b) **Stationary at the top.**



Explain your answer : ____

____

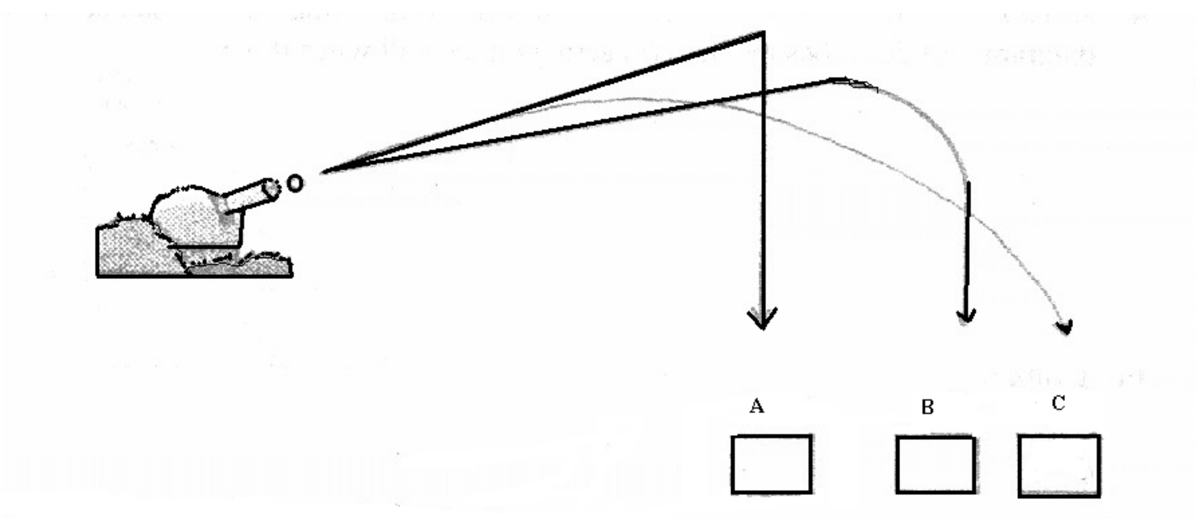
(c) On its way down



Explain your answer : ____

____

5. Choose the path taken by the cannon ball after it is fired.

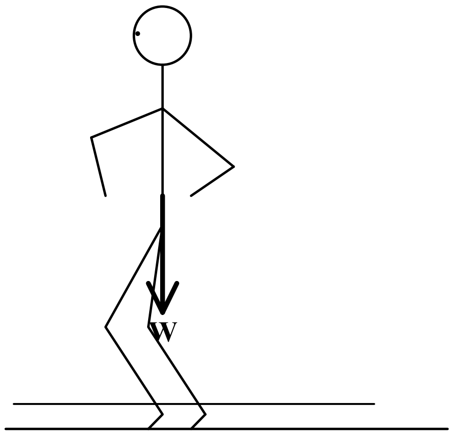


Give a reason for your choice : ____

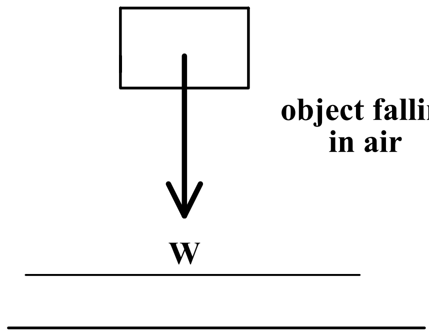
____

____

6. Identify the Newton third law force which is paired with the weight force W in situations (a) and (b). Draw the force on the diagram .



(a)

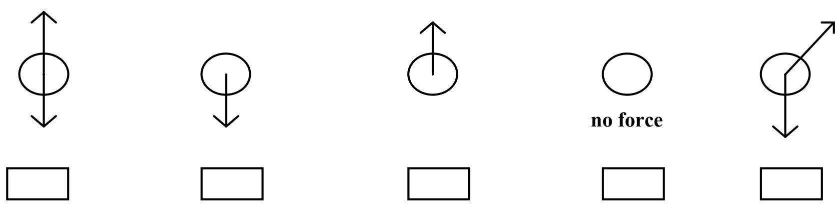


(b)

7. A ball is shot by a football player

Neglecting air resistance, what are the forces acting on the ball while it is :

(a) going up



Explain your answer : ______________________________

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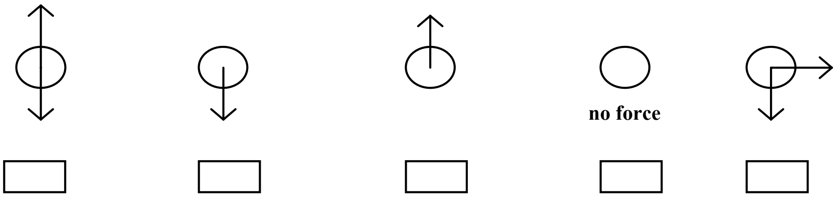
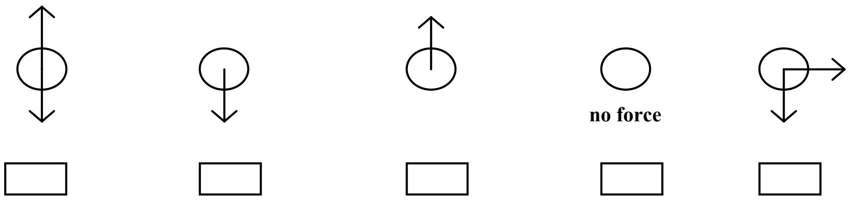
(b) at the top



Explain your answer : ______________________________

____

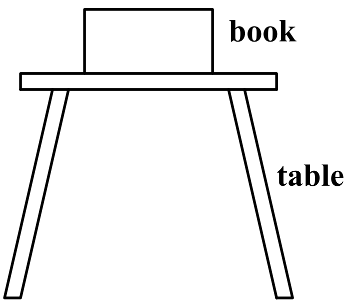
(c) going down ?



Explain your answer : ______________________________

____

8.



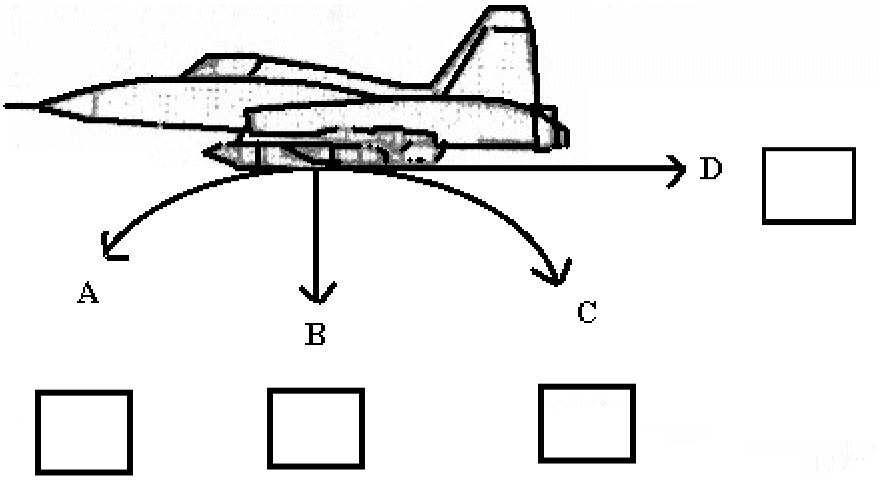
Are there any forces on the book ?

Yes ☐

No ☐

If you think there are forces present, draw the force(s) on the diagram, and name them.

9. A plane moving at a high velocity drops a bomb. Which one of the instances A,B,C, or D, best describes the path taken by the bomb when it is released ?



Explain your choice : ____

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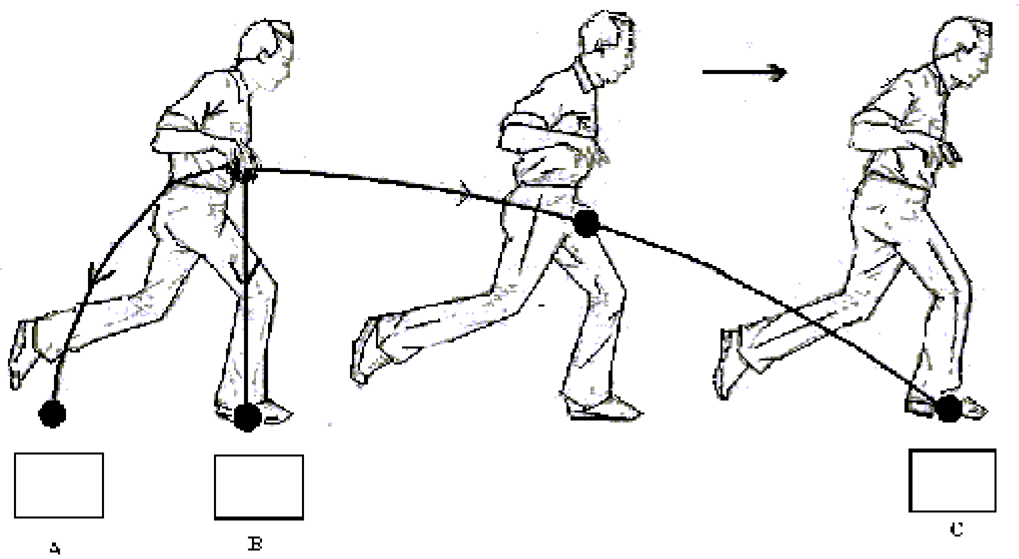
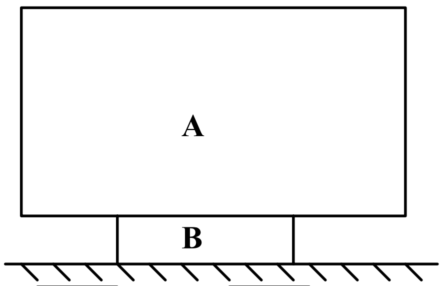
10. A man is running with a constant velocity in the direction shown above. He drops the ball while he is running. What is the path taken by the ball?



Explain your choice : ____

____

11. A large mass A rests on a small mass B.



Does A exert a force on B ? ☐ Yes ☐ No

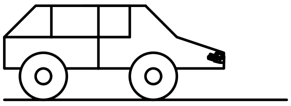
Does B exert a force on A ? ☐ Yes ☐ No

If you think forces are present, comment on the size of these forces .

____

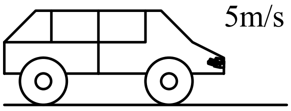
____

12. Consider the different situations and say whether you think a horizontal resultant force is acting and why you think so.

(a) 

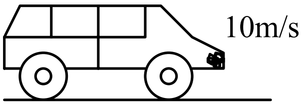
Car parked stationary.

____

(b) 

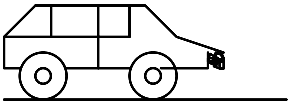
Car moving forward a uniform velocity of 5m/s

____

(c) 

Car moving forward at a unifrom velocity of 10m/s

____

(d) 

Car starts moving and speeds up.

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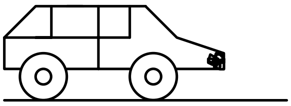
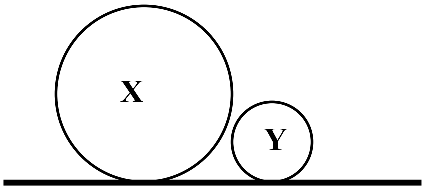
(e) 

A car braking until it stops

____

13. A small ball Y is stationary(not moving). The big heavy ball X hits it.



(a) Is there a force from heavy ball X on the light ball Y at the moment the balls hit ?

☐ Yes ☐ No

(b) Is there a force from light ball Y on the heavy ball X?

☐ Yes ☐ No

If your answer is yes to both, what can you say about the size of these forces ?

____

____