The Effect of PowerPoint and Traditional Lectures on Students’ Achievement in Physics

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Received: 08.11.2010 Revised: 02.08.2011 Accepted: 08.08.2011

The original language of the article is English (v.8, n.3, September 2011, pp.176-189)

ABSTRACT

The effect of PowerPoint in physics education is continuously debated, but both supporters and opponents have insufficient empirical evidence. PowerPoint’s use in physics lectures has influenced investigations of its effects on student achievement (e.g., overall exam scores) in comparison to presentations based on traditional lectures (e.g., “chalk-and-talk”), and PowerPoint-assisted lectures. Thus far, comparisons of overall exam scores have received mixed results. The present study classifies overall exam scores into auditory, graphic and figures, and slides scores to reveal new insights into the effects of PowerPoint presentations (PPP) on student achievement. Analyses considered the success of the lecture information that was presented to students without the use of PowerPoint (i.e., traditional lectures), as well as auditory and visual information displayed on PowerPoint slides. Data were collected from 90 student teachers via pre- and post-tests. The students at experimental group who participated in lectures supported by PPPs had higher grades than the control group who were solely taught through traditional presentations. The present study supports the premise that the “intelligent use” of PPPs in physics instruction is capable of increasing the students’ success.

Keywords: PowerPoint Presentation; Physics Lecture; Student Success.

INTRODUCTION

In the last twenty years, in a manner that paralleled the application of various other approaches, models, and strategies to improve student achievement through the presentation of visual information with lectures has gained prominence: namely, the projection of information directly from a computer onto a screen (e.g., PowerPoint presentations, pr PPPs). To emphasize particular points, many lecturers use written material presented on a chalkboard, whiteboard, or by PPP on computers. In fact, many colleges and universities have rooms or mobile carts that are equipped with the technology that is required for any instructor to display information in this manner. Furthermore, some administrations are pushing for instructors to use this technology (e.g., Carlson, 2002).
PowerPoint is a software tool that has become a presentation staple in lecture halls, conference rooms, and through the application of computer-based training. It is used in over 30 million presentations a day, and its software is on 250 million computers worldwide (Alley & Neeley, 2005). Initially, PowerPoint was developed to improve learning by providing the means to develop presentations that are more structured and interesting to audiences (Amare, 2006). Researchers have examined the benefit that these types of presentations bring to various audiences. Overall, research indicates that students prefer PowerPoint-type presentations to traditional lectures (Cassady, 1998; Gok & Sislay, 2008; Susskind, 2005). Unfortunately, information on whether computer presentations improve student performance is much less clear.

Several studies point to the idea that graphics improve student recall (Chan Lin, 2000; Szaba & Hastings, 2000). However, many courses that adopted multimedia presentations have not shown a corresponding increase in student performance (Stolo, 1995; Susskind, 2005; Szaba & Hastings, 2000).

PPPs can be as simple as consisting only of text on a colored screen. Presentations can also be complex and include tables, pictures, graphs, sound effects, visual effects, clips, etc. The effectiveness of PowerPoint and other multimedia presentations may depend on the complexity of the material that is being presented. In fact, several researchers have demonstrated that material, such as interesting but extraneous text (Schraw, 1998), irrelevant sounds (Moreno & Mayer, 2000) and irrelevant pictures (Mayer, 2001), can reduce comprehension.

Some lecturers state that PowerPoint inhibits the presenter-audience interaction (Driessnack, 2005), limits the amount of detail that can be presented (Tufte, 2003), and reduces a presentation’s analytical quality (Stein, 2006). On the other hand, supporters claim that PowerPoint improves learning (Lowry, 1999), invokes audience interest (Szaba & Hastings, 2000), and aids explanations of complex illustrations (Apperson, Laws, & Scepansky, 2006). In short, all software has advantages and disadvantages, and this debate highlights the fact that PowerPoint is no exception.

There are many factors that affect student success in physics courses. In this study, however, we will try to determine how success is influenced when lectures are solely presented in PowerPoint format. Although the use of computers has become widespread in academia since the eighties, physics PPPs have been discussed in order to better understand intricate topics (Bartsch & Cobern, 2003; Gok & Silay, 2008; Nouri & Shahid, 2005).

In general, physics lessons are taught in a traditional manner within the classroom setting because of the nature of physics topics and depending on the students’ habits. Therefore, the lectures have become monotonous, abstruse, and dependent on memorization skills. To be successful in a physics course, students should possess a good cognitive understanding ability, interpretation skills, math knowledge, and imagination. Therefore, the physics lecture is perceived as being quite difficult in some countries (Erdemir, 2009; Lyons, 2004; Trumper, 2006). The first reason why such a perception is potentially true is that the subject may be taught in a way that fails to correspond to the nature of physics and the students’ perceptions, thereby disregarding the need to highlight and mentally combine visual and verbal knowledge. The ineffective application of planned techniques can be shown as the second reason for the problem or perception. The combination of these two challenges causes students to be unsuccessful in physics education (Gok & Silay, 2008; Redish, Saul, & Steinberg, 1998; Trumper, 2006). Visual teaching methods that include the use of PPPs can be used to overcome this perception and increase students’ initial success.

Numerous studies have been conducted to determine whether or not PPPs affect the students’ success in physics instruction. Studies have revealed that the reason for success in
physics education have been associated with students’ motivation, interest, and the use of PPPs in the classroom setting (e.g. Craker, 2006; Normah & Salleh, 2006). Furthermore, studies have consistently indicated that students generally believed that the use of PowerPoint facilitated their learning and retention (Apperson, Laws, & Scepsansky, 2008; Mantei, 2000; Rankin & Hoaas, 2001; Szaba & Hastings, 2000). Therefore, the use of the PPPs to increase student teachers’ achievements should be considered as an important step in science education.

Students who were exposed to teaching methods with PPPs emphasized that their interest and achievements were improved. They said that PPPs enhanced their learning and success (Frey & Birnbaum, 2002; Rickman & Grudzinzi, 2000) because they were able to see the notes (e.g., slides and texts) on the screen and easily follow the subject. Moreover, research has indicated that the sole use of traditional teaching methods has negative effects on students learning or comprehension of physics concepts (Araujo, Veit, & Moreira, 2004; Susskind, 2005). So, we can conclude that we need to implement contemporary teaching methods, tools, and technology (e.g., PPPs and computerised teaching) into physics education in order to increase the level of students’ academic success.

Educators hypothesize that the use of PPPs in physics courses aims to encourage students’ active involvement in physics teaching and learning (Blas & Fernández, 2009; Gay, 2009). It enables students to learn, interpret the information, and retain the knowledge for a long time. Further, it attracts the students’ attention to the subject, makes the lesson easy to learn, and helps them to memorize abstract and concrete information (Erdemir, 2009; Savoy, Proctor & Salvendy, 2009; Wofford, 2009). Students appreciate the details, distinctive features, and critical points in the figures on the slides when graphic presentations are used. Hand-drawn figures cannot be copied onto the board. The impact on the success of this type of drawing is not as great as PPPs within the classroom setting (Bartsch & Cobern, 2003; Yucel, 2007).

When the researchers used the presentation graphics, the figures and graphics were more remarkable and clear in comparison to traditional teaching methods in which teachers only drew pictures or graphics on the board. Moreover, with presentation graphics, teachers can show many more pictures in less time. They can make rotate images in order to compare pictures. As a last advantage of presentation graphics, the use of colourful and remarkable signs on figures and graphics in PPPs might attract student teachers’ attention to physics topics. Moreover, selections of pictures and graphics from daily life experiences and the ability to enjoy sufficient time to discuss and question these figures and graphics in PPPS might influence student teachers’ achievements in a positive way. Unfortunately, most of these opportunities do not exist in traditional teaching methods.

If instructors are conducting presentations in a dark to a semi-dark room, it is difficult for them to maintain eye contact with their audience. The speed of the presentation may make it much more difficult for them to explain each of the points that they wish to communicate and it becomes challenging for them to read out their notes that correspond to the material. When the presentation is in progress, the instructors will not be able to look away from the slides because they will not know which piece of information will come next. The presenter’s dependence on the computer to advance the slides is a distraction and makes it difficult for them to give their full enthusiasm and attention to the material.

The usage of PowerPoint software and computers in physics instruction began in the eighties. Since then, there is a wide debate about the influence of PowerPoint-assisted teaching on student success in physics courses (Chonacky, 2006; Kenny, Bullen, & Loftus, 2006). However, the studies point out that there are positive or negative relationships between achievement and PPPs in physics instruction. The current study was conducted to determine
whether or not the use of presentation graphics (i.e., PowerPoint) in physics courses affected student teachers’ success in the physics course. We believe that it is important to determine the students’ success level in two different methods, such as the PPP and “chalk-and-talk” approach, which are used to teach physics topics. Thus, a classroom setting was used to investigate the differences in student achievement when they are exposed to traditional and PowerPoint lectures.

The objective of this study was to investigate whether or not the use of PPPs had an effect on science student teachers’ success in a physics course.

In this research, it is hypothesised that there is a significant difference between achievements of science student teachers for the PPP and traditional lecture (“chalk-and-talk”) formats.

METHODOLOGY

a) General Background of Research

The pretest-posttest control group research design (Fraenkel & Wallen, 2006) guided the present study. In this design, two groups of subjects are used, with both groups being measured twice. The first measurement is designated as the pretest and the second is named the posttest. These measurements are collected at the same time for two groups of subjects (Fraenkel & Wallen, 2006). In this section, the research sample, the instrument, procedures, data collection, and data analysis are presented.

b) Research Sample

This study was conducted with 90 science student teachers (i.e., 40 females and 50 males; aged 17 to 23—M = 19.18, SD = 4.13) who were conducting introductory physics courses in the fall 2008 academic semester. These science student teachers were enrolled in the department of science education in a large university in eastern Turkey. Science teachers STs must complete this course during their first year because it is a prerequisite for future physics courses. The science student teachers’ participation in the study was voluntary. Both the experimental and the control groups consisted of 45 science student teachers, and each completed the tests. One cohort of STs was randomly attributed as a control group and the other was assigned as an experimental group.

c) Instruments

The Force Concept Inventory (FCI) was administered as a pre-test at the beginning of the physics course. The FCI is the best-developed and most widely used diagnostic test in physics (Hestenes, Wells, & Swackhamer, 1992; Hake, 1998). The instrument revised by Hake and Hestenes (1995) contains 30 items with subscales that address the Newtonian concept of force (i.e., -Kinematics, the first law of motion, the second law of motion, the third law of motion, superposition principle of forces, other kinds of force (e.g., solid contact, gravitation etc.).

After completing the physics course, the students were administered the mechanics baseline test (MBT) as the post-test. The MBT with 20 items--some of which involve simple calculations without a calculator-- is more difficult than the FCI (Hestenes & Malcolm, 1992). It focuses on concepts that can be understood only after formal training in Newtonian mechanics).

The MBT included 25 questions, briefly, the researcher translated questions from English to Turkish. In order to check and establish the validity and reliability of the test, 45
students from two different classes of the same department were pilot-tested. After this application, in cooperation with two measurement and assessment experts and physicists, any incomprehensible and unanswered questions (five items) from the test were deleted (Appendix 1). In the reliabilities study, Cronbach’s alpha for scales were 0.83 (MBT).

d) The Content and Structure of Presentation Graphics

While the control group was only exposed to the traditional teaching method (e.g., lecturing), the experimental group observed presentation graphics as well as the traditional teaching method. The presentation graphics were a kind of PPP that was prepared with the help of Microsoft Office Power Point 2003 program. The presentation graphics mostly consisted of certain components (e.g., figures, graphics, and texts). These components for each physics topic (e.g., vectors, motion in one dimension, planar motion (two dimensions), particle dynamics I and particle dynamics II) were reflected on computer screens. In the first week, the presentation graphics including figures, texts, and vector-related images were presented to the STs. In the second week, presentation graphics including figures, texts, and motion-related images that pertained to one dimension were presented to the STs. In the following weeks, this method was retained for all of the remaining course topics. All of the presentation graphics implementation lasted for eight weeks. In order to provide a better understanding of physics topics, the graphics and figures were selected from daily life. For example, with respect to the topic of “motion in one dimension,” the figure explaining balloon movement was selected. Overall, the texts, graphics, and figures were colorful and simple to improve students’ achievements in physics courses. Generally, the principles related to the physics topics were presented visually. For example, on the subject of “horizontal shot,” this event was presented with the picture in the presentations graphics. Therefore, the STs easily observed all steps of “horizontal shot.” Moreover, when the STs wanted to take notes about important parts of presentation graphics content, sufficient time was allocated to them. As a last note, when it is necessary, the course instructor read some presentation graphics, including texts about the topics. At the end of the presentation graphics lecture, the instructor summarized the related topic. If the STs asked questions about the topic, the instructor returned to the related presentation graphic and provided necessary information with the help of related presentation graphics (Appendix 2).

e) Procedures

The lecture delivery style was composed of the traditional presentation (i.e., lecture without slides) and the PowerPoint presentation (i.e., lecture with slides) in the physics courses. Traditional lectures or lecturing methods include the lecture and the chalkboard presentation, which is often referred to as a “chalk-and-talk.” Chalk and talk” methods include writing on the blackboard, references to maps, traditional/conventional methods, direct speech, and other basic materials in the classroom during regular course lectures (Apperson et al., 2008). The majority of the material was verbally presented in the lecture. Graphs and figures were drawn on the chalkboard when illustrations were needed. There was no other equipment used for presentation of the information to the control group. The PowerPoint lectures consisted of the instructor and the corresponding graphics presentations. The presentations were reflected from a laptop on the screen using PowerPoint software. Only basic text, tables, and diagrams related to subjects in mechanics were presented. The majority of the material was presented on the laptop and presentations were supported verbally in order to teach the student teachers in a more comprehensive manner.

The same physics topics were taught to both groups by the same instructor and on the scheduled time and day (i.e., two days per week--totally four hours) on a weekly basis for
eight weeks. The course instructor used the same textbook, tests, and lecture materials during
the instruction; the only difference in the experimental group was the use of the PPP as a
supplement to the traditional lecture. The content of the course consisted of a group of
mechanics topics (e.g., vectors, motion in one dimension, planar motion (two dimensions),
particle dynamics I, and particle dynamics II). Both groups were taught the same topics
related to the mechanics. The course instructor used the laptop and projector to assist in his
PowerPoint presentation. The “intelligent use” of the PPP was administered in order to curtail interruptions to the instructor’s presentation: The PPP was closed for a short time after a brief lecture and questions and explanations had been discussed with the instructor. The students were focused solely on the points presented in the slides, and they were able to focus on the instructor’s explanations. The instructor tested whether or not they comprehended the concepts and topics that had been taught.

The procedure followed in the present study is summarized as below:

- The STs were given the FCI as a pre-test, and then the teaching physics was started.
- The experimental group was instructed with the presentations graphics as well as lecturing, and the control group was instructed with only lecturing. The instruction period was completed in 8 weeks (32 hours).
- Students from both groups completed the posttest (the MBT).
- Since both groups were presented topics related to mechanics, the MBT was applied to both groups by the instructor after the instruction was over and the data had been collected.

When analysing the data obtained from both groups, t-test statistics were used to determine whether or not the use of the presentation graphics (i.e., PowerPoint) affected the student teachers’ success in the physics course.

**FINDINGS**

a) Effect of the PPP on Student Teachers’ Success in Physics

The t-test was applied to verify whether or not there was a significant difference between the mean scores of the student teachers in the experimental and the control groups before instruction.

**Table 1. T-test results of the pre-test scores of the experimental and the control groups in the Readiness Test.**

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>45</td>
<td>61.02</td>
<td>13.39</td>
<td>88</td>
<td>0.00</td>
<td>.317</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>CG</td>
<td>45</td>
<td>60.92</td>
<td>13.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant at level p< 0.05; EG: Experimental Group; CG: Control Group

When the mean of the pre-test scores and standard deviations of the FCI were calculated for both groups, the achievement means of the groups were found to be the same, as is seen in Table 1. These results indicated that the student teachers’ achievement levels in both groups were the same before instruction. As a result, it was determined that there was no statistically significant difference between the pre-test scores of the experimental and control groups ($t_{(88)} = 0.00$, $p<.317$) before instruction.
Table 2. T-test of the post-test scores of experimental and control groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>45</td>
<td>72.59</td>
<td>15.05</td>
<td>88</td>
<td>10.86</td>
<td>.005</td>
<td>P&lt;.05*</td>
</tr>
<tr>
<td>CG</td>
<td>45</td>
<td>64.52</td>
<td>12.57</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Significant at level p< 0.05; EG: Experimental Group; CG: Control Group

As shown in Table 2, the mean score of the experimental group was higher than the mean score of the control group. These results show that there is a statistical difference between the scores of both groups (t(88)= 10.86, p<.005) after instruction. This significant difference indicated that the use of PowerPoint for teaching had a positive impact on student teachers’ success in physics courses.

b) Determining the Effect of the PPP on the Student Teachers’ Success after Instruction

The t-test was conducted in order to determine whether or not there was any statistical difference between the pre- and post-test mean scores of the experimental group.

Table 3. The difference between pre-test and post-test scores of the experimental group

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>45</td>
<td>61.02</td>
<td>13.39</td>
<td>88</td>
<td>-6.51</td>
<td>.000</td>
<td>p&lt;.05*</td>
</tr>
<tr>
<td>Post-test</td>
<td>45</td>
<td>72.59</td>
<td>15.05</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Significant at level p< 0.05

The results of the test indicated that the pre-test mean score of the experimental group was M = 61.02 before instruction, and the post-test mean score was M = 72.59 after instruction. The standard deviations of the post- and pre-test scores of the experimental group were calculated as SD = 13.39, SD = 15.05, respectively, as seen in Table 3. According to the results of the test, there was a significant difference between mean scores of the pre- and post-test of the experimental group (t(88)= 6.51, p<.000).

Table 4. The difference between pre-test and post-test scores of the control group

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>45</td>
<td>60.92</td>
<td>13.48</td>
<td>88</td>
<td>-4.21</td>
<td>.056</td>
<td>p&lt;.05*</td>
</tr>
<tr>
<td>Post-test</td>
<td>45</td>
<td>64.52</td>
<td>12.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at level p< 0.05

The pre-test mean score of the control group was M = 60.92, the post-test mean score was M = 64.52, and the standard deviations of the pre- and post-test scores of the control group were calculated as SD = 13.48, SD = 12.57 after instruction, respectively, as seen in Table 4. According to these results, there was a slight difference between the pre- and post-test mean scores of the control group after instruction (t(88)= 4.21, p<.056).

DISCUSSION

The purpose of this study was to investigate whether or not the use of presentation graphics (PowerPoint) affected students’ success (i.e., when compared to a traditional lecture) in physics courses. The mean scores of both groups were the same before instruction, as seen in Table 1. It can be said that achievement levels of the student teachers related to mechanics topics were the same at the beginning of the course.

According to the post-test results, the students who were exposed to PPP-supported physics lectures were more successful than those in traditional lectures after the instruction.
The post-test score of the experimental group was higher than that of the control group. This result can be accepted as evidence that the presentation graphics (PowerPoint) method has positively affected student teachers’ success in the physics course and, furthermore, this result has been supported by other studies in science education such as those conducted by Kaptan and Korkmaz (2002) and Tao (2001). They stated that the teaching method that included presentation graphics had a positive effect on student achievement at every teaching level. Thus, the stated hypothesis that there was a significant difference between student achievements in the experimental and control groups after they were exposed to the PPPs and traditional “chalk-and-talk” lectures was supported.

When students are taught the PPP-supported physics course, they are able to interpret and understand the physical terms, principles, and concepts based on the knowledge taught while making a connection between knowledge and formulas. In addition, the present study has indicated that PowerPoint-aided education enhances student teachers’ achievements and concentrates their students’ attention on the physics course. The work of Bartsch and Cobern (2003), and Gonen and Basaran (2008) supports this idea. They have expressed that PowerPoint-aided education facilitated learning, attracted students’ attention and enhanced his/her motivation.

Complex and coloured shapes that provide a suitable enough rendition of the original image cannot easily be drawn by hand on the board. Students also get difficult the understanding of physics lesson. However, texts and complex figures in a PPP can be easily reflected from a laptop onto a screen. In this way, coloured and concrete presentation graphics can help students to better understand and remember knowledge during physics exams because such graphics are identical to the original image. Therefore, the rationale behind the success of the students in the experimental group stems from the alleged views. According to the present research results, a teaching method that incorporates PPP positively affected the student teachers’ achievement. Additional studies support this view (Bartsch & Cobern, 2003; Gok & Silay, 2008).

It is also important to note that when a PowerPoint slide is shown on the screen, the students focus on the slide. In during of the presentation, the instructor-student interaction is occasionally interrupted. In addition, students had an opportunity to take notes. When learning occurs, students will place relevant words into their auditory working memories and relevant images into their visual working memories. They then organize the information separately in their auditory and visual memory and, finally, integrate these representations with prior knowledge. This idea has been supported by Mayer’s cognitive theory of multimedia learning (2001). Similar discussions had been put forward by Bohlin & Milheim (1994) and Moore (1993), who highlighted that PowerPoint-aided presentations enhance an adult student’s success, attention, and motivation.

CONCLUSIONS

Several results can be drawn from the present study, in which PPP-aided instruction affected students’ success in physics courses. Indeed, this method can be more effective in physics instruction.

The present study revealed that graphics were not necessary for simple declarative information, but could help students to better understand more difficult, complex, or abstract ideas that are presented in lectures. Therefore, the teaching method supported by PPP had a positive impact on the student teachers’ achievement. According to this study, that positive impact can be related to the use of PPPs, because they helped to improve organization, clarity, and comprehensibility of the physics lessons.
The results indicated that verbal explanation was necessary after teaching supported by PPP, because they were expected to more comprehended concepts and complex graphics, figures, abstract concepts and physics principles.

Consequently, according to the results of this research, the PowerPoint can be an optimal or more appropriate way for student's learning styles to be utilized in physics education. It is possible to state that PowerPoint-aided education has a positive effect on the learning, understanding, and success of students. Some advantages of this method can be that it helps students to construct meaningful learning and fosters an awareness of fine details of complex topics.

The present study provides an important contribution to the academic community because the intelligent use of PPPs in physics teaching can shed some light on how to help students to better understand scientific concepts and apply them in their lives. Therefore, these findings give us some insights into how we can improve student success in physics teaching and learning in the classroom setting. Based on the results of this study, we recommend that the use of a PowerPoint-based learning system requires reinforcement from an instructor, especially when applying such a system to students with different abstract reasoning abilities.
REFERENCES


Appendix 1

1. Three identical blocks slide down the frictionless slopes A, B and C of equal heights as shown. All three blocks are initially at rest. Which block would reach the ground at the greatest speed?

A. block A
B. block B
C. block C
D. all three blocks have the same speed
E. block B and C

2. A block is sliding up a rough slope as shown. The angle between the force of kinetic friction acting on the block and the force of gravity acting on the block is:

A. less than 90 degrees
B. equal to 90 degrees
C. greater than 90 degrees
D. none of the above
E. not enough information to answer

3. One example of an object in equilibrium is:

A. a 2400-kg car, moving north at a speed of 90 km/h
B. a vertically thrown ball at the top of its trajectory
C. a satellite moving around the Earth in a circular orbit
D. a simple pendulum swinging in vacuum
E. a 1500-kg truck, moving circular motion at a speed of 120 km/h

4. Two forces, of magnitudes 5 N and 15 N, are applied to an object. The relative direction of the forces is unknown. The net force acting on the object:

A. may not be directed perpendicular to the 5-N force
B. may be directed perpendicular to the 15-N force
C. may not equal to 5 N
D. may not equal to 15 N
E. may equal to 3 N

5. Three identical blocks are connected by ideal strings are being pulled along a horizontal frictionless table by a constant horizontal force F (see the diagram). What is the magnitude of force F is the tension of the string connecting blocks B and C is 60 N?

A. 60 N
B. 120 N
C. 180 N
D. 240 N
E. none of the above