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GRID METHOD APPROACH IN TEACHING BASIC VECTOR CONCEPTS FOR FUNDAMENTAL PHYSICS

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Abstract: Fundamental physics used a lot of basic vector concepts. Topics such as projectile motion, forces, momentum, static equilibrium and impulse require students to understand well the basic vector concepts. Many students have difficulty in understanding physics ideas and concepts because they could not grasp the vector concepts well. In this research, the grid method was introduced in teaching the vector concepts. Instructors would start with lecture on vectors and proceed with some exercises. The exercise requires the students to get the answer using a grid paper facilitated by the instructors. A seven item quiz was applied as pre-post test in order to evaluate the effectiveness of this method compared to the normal method. Two sets of data were analysed using paired sample t-test. The first set of data comes from the experimental group which uses the new method and the second set of data comes from the control group which apply normal method in introducing the vectors. When comparing the mean scores, 5.74 mean score is for the experimental group while the control group scored a mean of 4.11. The gain score for the experimental was 0.7 while for the control group was 0.3. The post test for experimental correct responses is higher compared to the control group after the grid method was introduced. This shows that the learning gain is higher and students grasp the concepts well and improve their understanding on basic vector concepts when mean score for students in experimental group is 5.25 while control group 4.43 from the final examination results that involve vector concept.

Keyword: Vector Concepts, Grid Method, Experimental Group, Control Group, Gain Score

I. Introduction

Vector is a mathematical concept that is integral in the learning of physics (Barniol & Zavala, 2014),(Buncher, 2015), (Meltzer, 2002), (Turnbull, Doughty, Sawtelle, & Caballero, 2015). Students may be able define vector as a quantity having magnitude and direction, but majority of them failed to solve physics problems involving vector concept (Barniol, 2014), (Kwon, 2013), (Barniol & Zavala, 2013). Since a substantial amount of the physics contents are based on vector concepts (Pepper, Chasteen, Pollock, & Perkins, 2012), (Barniol et al., 2016), (Zavala & Barniol, 2014), a lot of the students could not achieve a better grade or failed physics because they had a lot of misconception of the vector's properties (Nguyen & Meltzer, 2003), (Kwon, 2013), (Barniol & Zavala, 2009). Another challenge faced by physics' teachers and lecturers in particular is the attention span of the Z generation. Z generation also known as the post-millennial generation tend to have difficulties to focus for more than three minutes, (Vallon, 2016), (Corey Seemiller, 2016), (Darnell, 2009) .Active learning is one of the best ways to engage this type of students in learning difficult concepts and ideas. Therefore, a strong understanding of the vectors concept using a hands-on type of learning skill could solve the problem of learning physics concept.(Darnell, 2009)

Vector concepts used a lot in Foundation studies syllabus. The topics that involved vectors include, motion in 1D and 2D, Forces, Static Equilibrium, Momentum and Impuls, Electric and Magnetic, and Inductive. This shows that vector contribute more than 70% in the syllabus. Therefore the basic vector concepts are very important for the students to score their final examinations. At this institution, we prepare the students with strong foundation in science and mathematics as a pre-requisite to enter universities. Students come from high school or equivalent to GCE-O level. They have been exposed to vectors but lack the proper understanding of vectors. The topic of vector is taught during the first and second weeks (3 – 4 hrs). During these hours of lecture and tutorial, students have to quickly and effectively grasp the concept and ideas of vectors from definition till addition and subtraction of vectors.

Most researchers used additional worksheet (Wutchana, Bunrangsri, & Emarat, 2015), (Barniol, 2016) to improve student's understanding on vector concept. Most of the questions have figures or illustrations of vectors based on question with a single vector or multiple vectors(Wutchana et al., 2015), (Barniol, 2016). Some questions may

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require the students to sketch or draw the vectors on a plain paper, (Barniol, 2016)(Wutchana et al., 2015). In this study, grid method was proposed for teaching and learning of vectors. Students will be engaged in active learning throughout the lesson. In introducing this method, bear in mind that previous studies have shown that there are four major concerns for instructors to take into consideration (Wutchana et al., 2015) :

1. Instructors should start with introducing the vector concept based on the definition of the vector itself and briefly explain to students.

2. Instructors need to make students understand that a vector can be moved and while moving the magnitude and the direction must be preserved.

3. While adding two or more vectors, one vector’s tip must be attached to the other vector’s tail

4. The resultant vector is drawn from the tail of the initial vector to the tip of the final vector.

Based on these four major concerns, new lecture notes and the guided questions of vector using the grid method were designed. Hoping that this method could help students learn physics more effectively and reduce the difficulties in solving problems involving vector concept in topics such as forces, momentum, kinematics, electricity and magnetism.

There were three major parts in the lecture notes. The instructor will first introduce the vector quantities in particular the understanding of the meaning of magnitude and direction of a vector and properties of vectors. The second part is finding resultant of the vectors using addition of vectors. The third part demonstrates the difference between addition and subtraction of vectors by using the same vectors (Nguyen & Meltzer, 2003).

The grid method consists of notes and exercises using grid paper. This grid method used to highlight the mathematics concept behind the vector. This would be very useful for the students that having problems in mathematics. Therefore when started with introducing the mathematics then the students have clear picture on the basic vector concepts. This might help them to get more understanding the vector in physics and can easily solve the problems or the applications in other physics concept which is base on the vector concept.

Different with the tradisional or nornal method, lecturers will directly introuced students with the physics by assuming the students already clear the mathematics behind the physics. The fact is, most of the students fail to understand the physics concept and the application when they missed to understand the mathematics of the physics.

This method would slowly solve this problems escpecially for students that are very weak in their mathematics. Besides the exercise also will give more time for students to slowly understand the concept and use the concepts tosolve problems for further lesson which involve the vector concepts.

Basic vector concept involved the addition and substraction where students also need to clear the characteristics of the vector before able to solve the addition and substraction problems. Characteristics of a vetor is the magnitude and the direction of the vector.

II. Methodology

Participants

In our institution, we have 75 classes. This method was used to two classes for control and two classes for experimental. Two different instructors will teach two different methods to their students. Total samples are 200 students involve for this research.

To investigate the effectiveness of using the grid method on teaching the vector concept, the students are placed into two groups. The first group which is the control group is taught by an instructor using previous accepted method of teaching vector concept. The second group is taught using the grid method.

A quiz consisting of seven questions were used as pre and post-test. The quiz was chosen based on the vector concept covered for foundation levels (Nguyen & Meltzer, 2003) The questions were to evaluate the student’s understanding of magnitude and direction of the vectors, addition and subtraction of vectors and other properties of vector.

Quiz

The quiz would assess whether students can correctly identify vectors with identical magnitude and directions and whether they can carry out vector addition in one and two dimensions. On five of the problems, students are asked to give a free response or to select multiple options from a list. On the other two (#3 and #7), they are given possible choices. On four problems students are explicitly prompted to provide explanations of their work(Nguyen & Meltzer, 2003).

200 students were choose randomly as our sample from 3000 students that registered for physics courses at the Centre for Foundation Studies, Universiti Teknologi MARA, Kampus Dengkil. This small number of sample size was taken to test the effectiveness of the new approach in teaching basic vector concepts. For this experiment, the sample size can be any number as long as the results show the difference between the control group and the experimental group (Lenth, 2001).

The 200 samples were labelled with number 1-200. The data is keyed in based on the marks for each question. The data collected were pre test for experimental group, post test for experimental group, pre test for control group and post test for control group. Samples that obtained full marks for pre and post test were removed before the data were analysed. Hence, the number of sample became 97 for experimental group and 98 for control group.

We choose to analyse the data using paired sample independent t-test. By comparing the means of the control group and the experimental group, we can determine if there is a significant difference between the two groups. We also found the gain score using this equation (Wutchana et al., 2015):

$$g = \frac{posttest\_score - pretest\_score}{\max imum\_score - pretest\_score} \quad (1.1)$$

The student's learning gain was assessed by comparing the difference between their pre- and post-test scores to the maximum possible gain and this is called normalized gain (Hake, 1998). Normalized gain (g) is defined as the change in score divided by the maximum possible increase as presented in following.

In this study, the class average normalized gains (<g>) were calculated from the average of students' normalized gains (Bao, 2006). They were used to represent the effectiveness of the worksheet instruction. However, for the students who had full scores for both pre-test and post-test, their scores would be removed from the data set because the student performance was beyond the scope of the measurement instrument (Marx & Cummings, 2006). To see the progression in each problem, the normalized gains were then calculated separately for each problem by comparing the differences of students' correct responses between pre- and post test to the maximum possible gain of that problem.

The class average normalized gains were divided into three regions; high gain is where <g> is greater than 0.7 (<g>high> 0.7), medium gain with <g> between 0. 3 and 0.7 (0.3 ≤ <g>medium < 0.7) and low gain with <g> less than 0.3 (<g>low< 0.3). After Hake had proposed this analyzing method in 1998, normalized gain has been widely used by many Physics Education researchers (Celletta & Phillips, 2005; Stewart & Stewart, 2010; Celleta, Phillipss, Jeffery & Jeff, 2011).

III. Result And Discussion

Results were analysed using SPSS by comparing the means using paired sample t test. Table 1 shows mean scores for pre and post-test for both control and experimental.

TABLE I

Mean score and gain score for pre-post test on the two group

Group	Pre-test	Post-test	Sig	<g>
Control	2.45	4.11	0.000*	0.3
Experimental	2.48	5.74	0.000*	0.7

*Significant 2-tailed

Table 1 shows that the pre-test result for both group is insignificant. After going through the lectures and tutorial both group show an increase in their knowledge of vectors. However, when we compare the means for post-test of the experimental and control group, we observed a significant difference. The value of gain for the experimental group (0.7) is higher than the control group (0.3) which probably showed that the grid method helps students grasp the idea on the vector concepts better as supported by the study by (Wutchana et al., 2015).

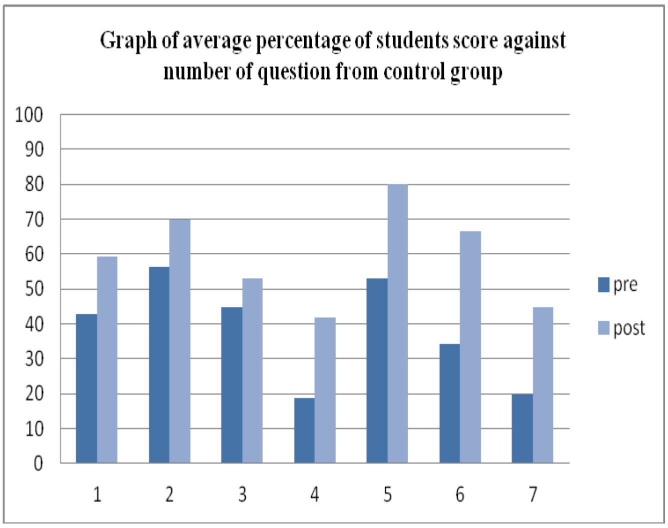

Figure 1 : Graph of the results of pre and post-test for control group.

Figures 1 and Figure 2 show the students' performance on each question for the control group and the experimental group respectively. The percentage of correct responses to each quiz item for pre and post-test are shown in both Figure 1 and 2. From figure 1 we can see that there are still have improvement to students score even not very high.

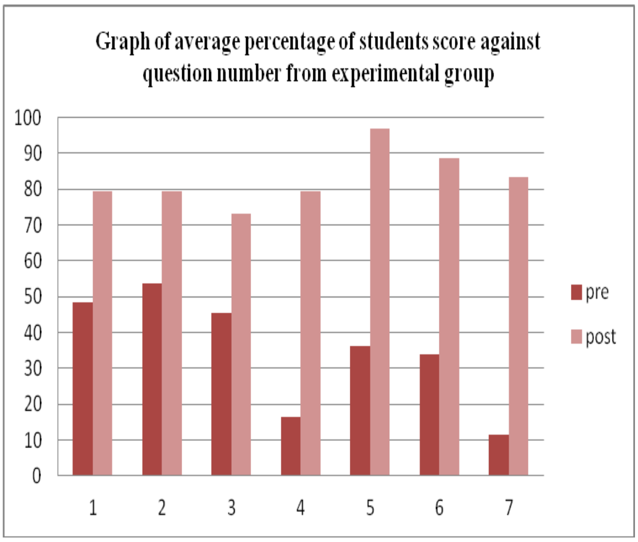

Figure 2 : Graph of the results of pre and post-test for experimental group.

From Figure 1 and Figure 2, there are significant differences between pre and post test results for both groups. Students show improvement in the test score for all questions for both groups. However, the experimental group showed a marked improvement in the test score especially for questions 4, 5, 6, and 7 which suggest that students in the experimental have a better understanding of the concepts in vector.

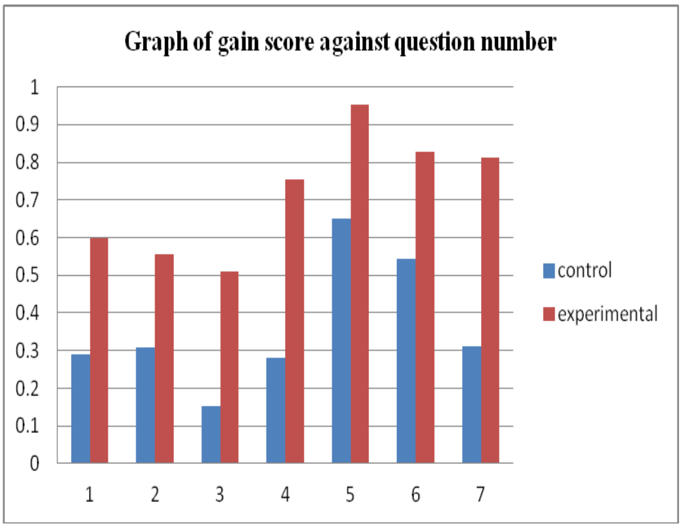

Figure 3 : Graph of gain score against question number for both groups.

Figure 3 compares the student's learning gain that were calculated using the equation 1.1 between control group and experimental group. The graph clearly shows that the learning gain for students in experimental group is higher compared to the control group that was taught using the normal method of teaching basic concept on vector. The results suggest that this grid method approach in teaching basic vector concepts could be effective in teaching vector concepts especially to the millennial generations. Students showed higher improvement for question number 4 and 7. Question number 4 is the most common error done by the students while solving the addition for one dimensions problems. Especially in topic, impuls and momentum. Momentum involved motion before and after which students need to consider the magnitude of the velocity and the direction. This is because after the collision both might change. When the change is simply the opposite direction, we need to consider it experience impuls. When students fail to understand that the opposite direction means subtraction they would not able to solve the problems correctly. This method would give large contribution if students start to realize regarding this matter.

Questions 1 and 2 in the quiz are to identify the magnitude and direction of one (1D) and two- dimensional (2D) vectors. Even though these are basic concepts in vector which they have learn in school, the grid method helps to increase the students' understanding of the properties of vector as shown from the Figure 3. For question 3, 4, 5, 6, and 7 students need to apply the knowledge on vector addition in 2D. Question number 4 is about adding two 2D vectors with opposite directions. Most students using the grid method are able to add correctly taking into consideration the vector's directions but majority of students in the control group gave the wrong answer because they did not consider the vector's direction. Deep analysis of the students' responses indicates further that common student error is selecting a vector with its direction just closing to the given vector but not exactly the same. Many physics instructors thought that this concept is not difficult and so they paid less attention and went over this point quickly causing some difficulties to students. However, what we found here shows that the student did not realize that vectors of the same direction have the same angle with respect to the vertical or the horizontal axis.

In question 5, students were asked to draw the resultant vector when adding two 2D vectors. Students that were treated with the grid method were more conscious of the importance of direction of the vector when solving this type of problem since the grid method emphasizes the importance of the direction. The grid method enables student to see different resultant vectors if they ignore the direction of the vectors that were added. On the other hand, the control group tend to treat vector as simply having magnitude without considering the direction.

Question number 6 tests the students' understanding of subtraction of vectors in 2D. The negative of a vector means the opposite direction of the vector. Hence, the subtraction of a vector is actually just the addition of the negative of the vector. Students who fail to understand the concept of the direction of vector will not be able to answer this question correctly. Students in the experimental group manage to understand well the concept of the negative of a vector. This is proven when they are able to answer and give the explanation to this question. The control group students, however, made the common mistake of ignoring the change of direction when adding the negative of a vector. For this part, lecturers need to stress out that the direction of the vector can be opposite with condition we put negative to that vector. Students should understand that the vector is negative because of the value or the magnitude but the vector become negative because of the direction. When there are 2D vector, it need to be resolve and from the resolution vector students suppose know whether the vector is negative or positive for each component.

The concept that was tested in question 7 was on the method of adding 2D vectors using either head to tail method or parallelogram method. Grid method encourage students to use head to tail method to find the resultant vector. Before using head to tail method they need to understand that when moving or translating a vector, the direction and magnitude is still preserved. For the control group, they were not able to apply the methods.

This study were extended further by looking at the students' performance in their final examination. The students score for questions related to the application of vectors normalized to be comparable to the mean score as in Table 1. Interestingly, the experimental group of students obtained a mean score of 5.25 while the control group obtained a mean score of 4.43. This result shows an almost similar score to the post-test for both control and experimental group.

IV. CONCLUSION

The results clearly show that the weakness of students in understanding vector concepts lie in the difficulty to imagine or correctly define the direction of a vector. The grid method has been shown to increase the student's awareness and understanding of the importance of the direction of a vector. The successful of this method not solely on the method but include the active learning that involved when students hands on doing the exercise together with their lecturers. This method involved two ways interactions which make students would not feel bored. This early intervention of sensing the importance of both properties of vectors will help the students in solving vector problem in forces, momentum, motion in one and two dimension and so forth. Therefore, grid method would be the simplest way in introducing vector concept at the introductory level of physics. We believe that when the basic vector concept is clear, then the students will be better prepared to face more challenging problems on vectors. This method, however still needs more research to prove its effectiveness.

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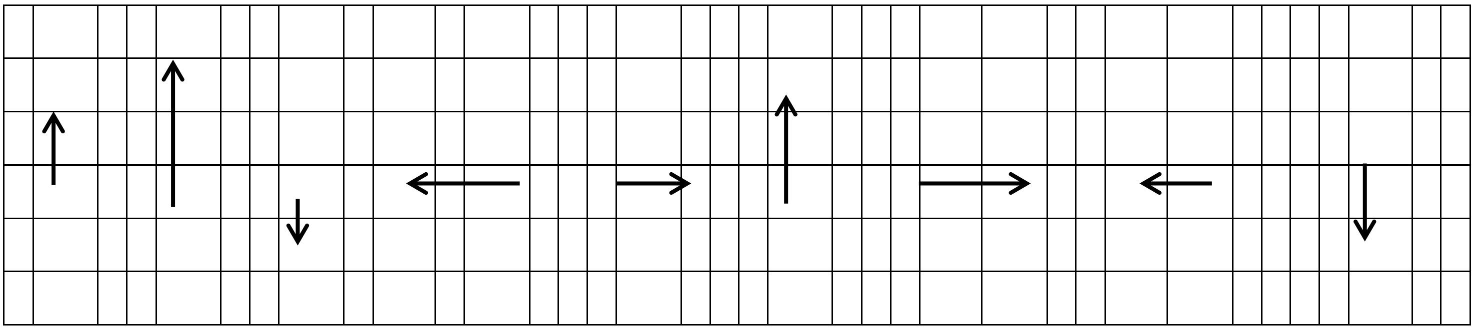
Appendix

Vector concept Quiz

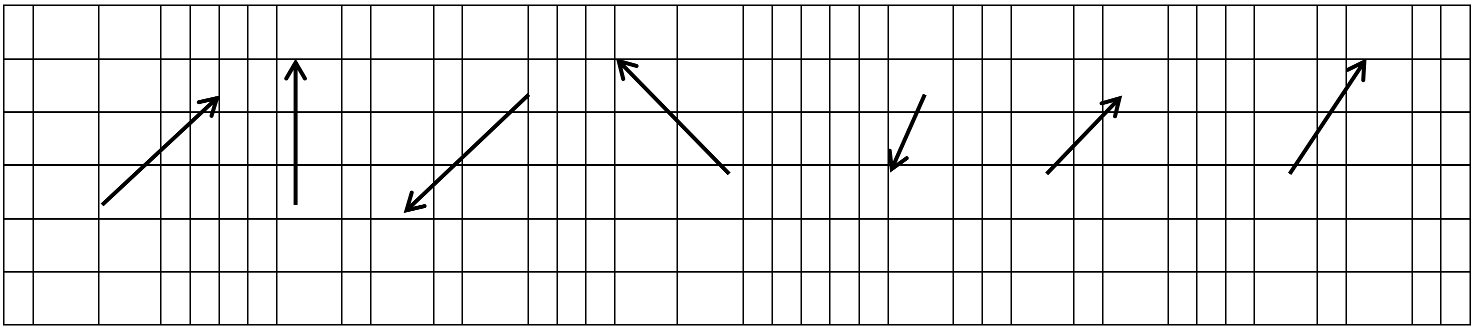
Name: ____________________ Student ID:______________________

Class: ______________________

1. Consider the list below and write down all vectors that have the same magnitudes as each other. For instance if vectors W and X had the same magnitude, and the vectors Y, Z and A had the same magnitude as each other (but different from W and X) then you should write the following : $|\mathbf{W}|=|\mathbf{X}|$, $|\mathbf{Y}|=|\mathbf{Z}|=|\mathbf{A}|$.

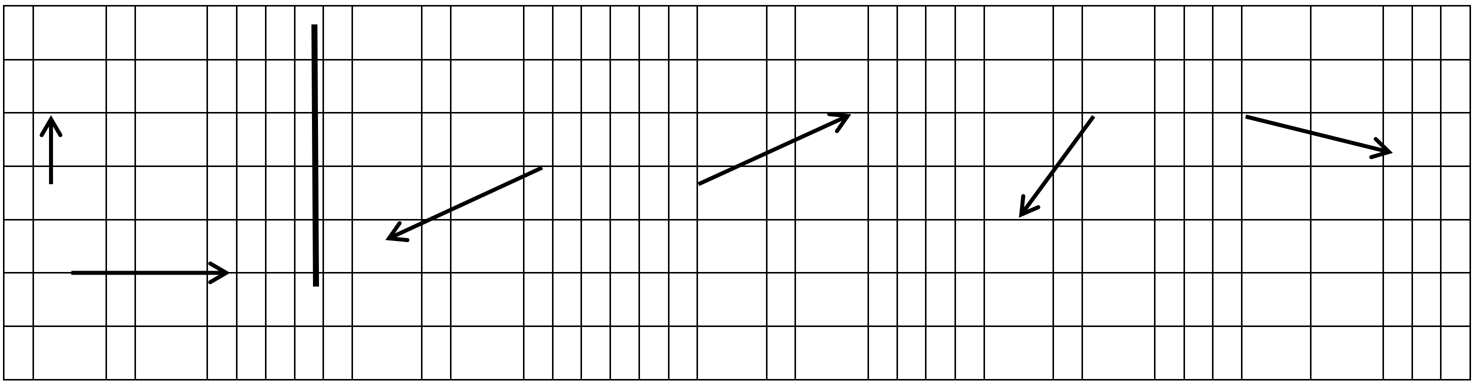


2. List all the vectors that have the same direction as the first vector listed, A. if there are none please explain why.



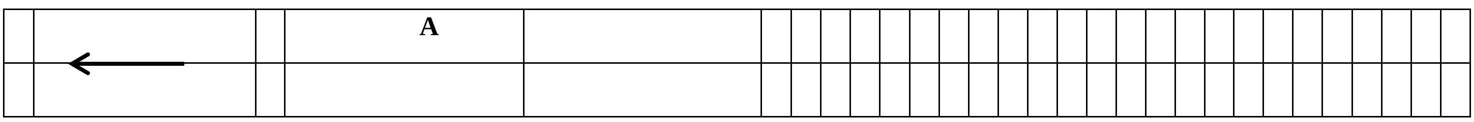
Answer :____________________ Explain ____________________

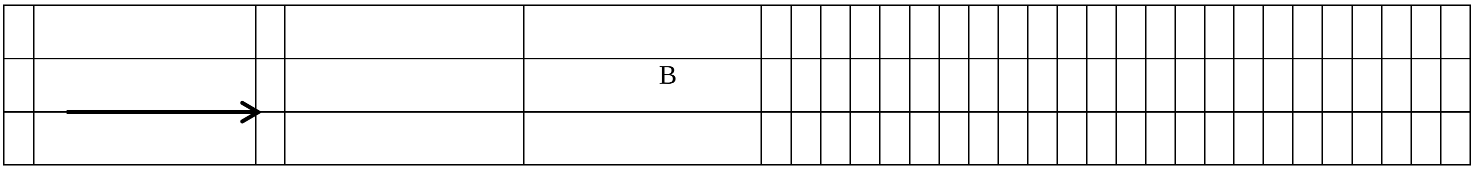
3. Below are shown vectors A and B. consider R, the vector sum (the "resultant") of A and B, where R=A+B. which of the four other vectors shown (C,D,E,F) has most nearly the same direction as R?



Answer: __________________________

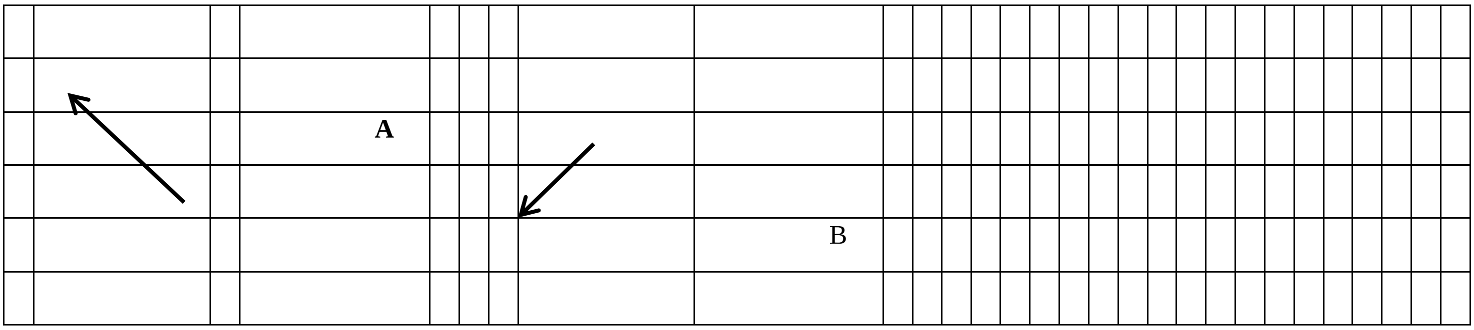
4. In the space to the right, draw R where R=A+B. Clearly label it as vector R. explain your work.



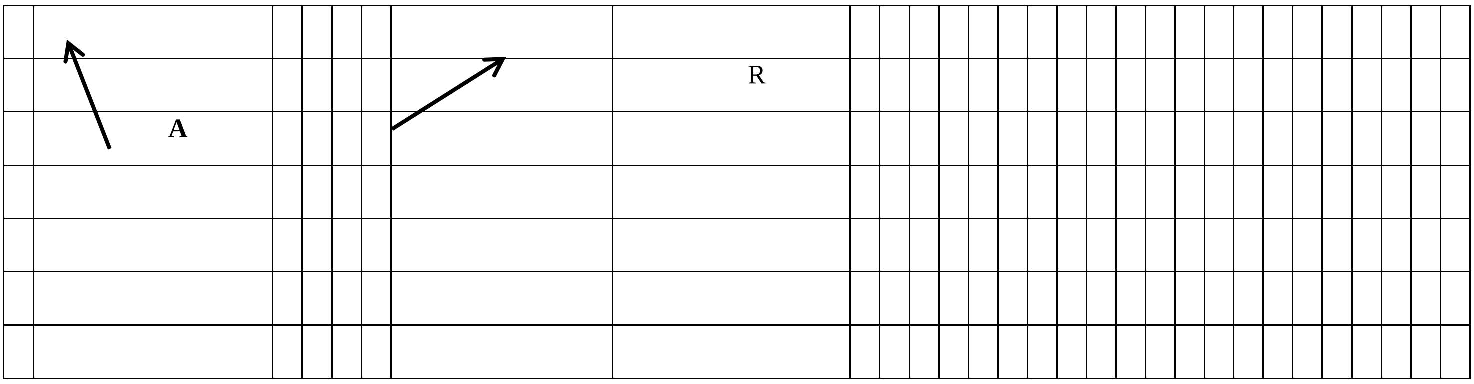


Explain ______________

5. In the figure below there are two vectors A and B. draw a vector R that is the sum of the two, (i.e., R=A+B). Clearly label the resultant vector as R.

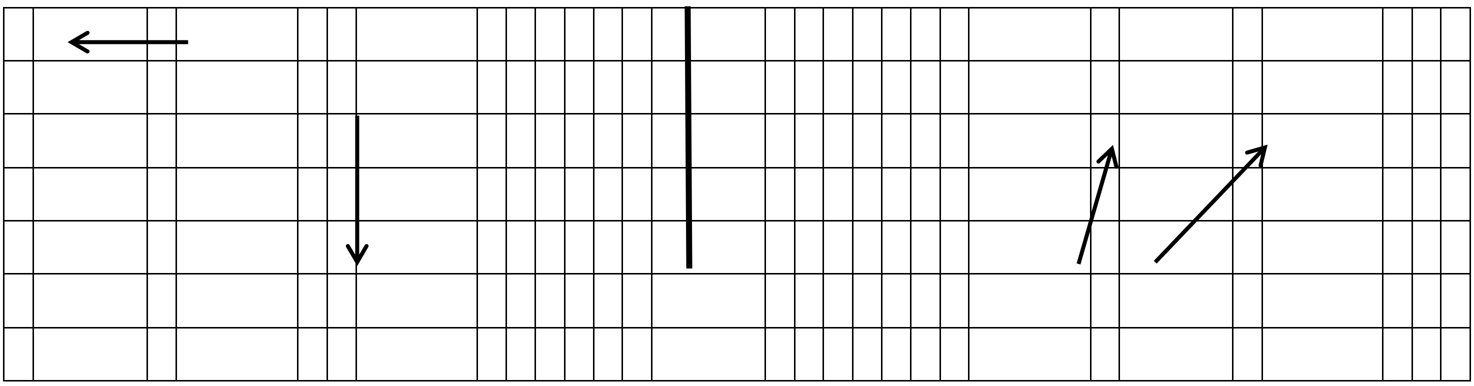


6. In the figure below, a vector R is shown that is the net resultant of two other vectors A and B (i.e., R=A+B), vector A is given. Find the vector B that when added to A produces R; clearly label it B. DO NOT try to combine or add A and R directly together! Briefly explain your answer.



Explain __________________

7. In the boxes below are two pairs of vectors, pair A and B. Consider the magnitude of the resultant (the vector sum) of each pair of vectors. Is the magnitude of the resultant of pair A larger than, smaller than or equal to the magnitude of the resultant of pair B? Write an explanation justifying this conclusion.



Explain __________________________