**DIAGNOSTIC /REMEDIAL TEST**

**07 VECTORS**

This test is one of a series in Introductory Physics made available on the Website of the School of Physics, Monash University, Australia ([www.physics.monash.edu.au/community](http://www.physics.monash.edu.au/community)).

This test is NOT for the purposes of assessment. It is to assist you in locating misconceptions and misunderstandings and generally to assist you in your study of Physics. You should work by yourself and at your own pace following the directions given. It is not necessary to attempt the test all at once. You may like to do it bit-by-bit, waiting until you have covered a particular topic in class or in your reading of your text book or you may like to "plunge in " before you begin your study of the topic.

Questions are on the left hand (even-numbered) pages. While reading or working on these, **keep the right hand (odd-numbered) answer page covered. DO NOT PEEK AT THE ANSWERS ON THE RIGHT HAND PAGE !**

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COVER THE RIGHT HAND (ODD-NUMBERED) PAGES

DO NOT PEEK

When you are concerned with motion in two or three dimensions some quantities such as displacement and force must be added in a special way. The following questions are to help you to understand and use vector addition methods.

1



1

Consider a journey from a starting point O consisting of two parts, a displacement of 2 km due North to point A, followed by a displacement of 2 km due East to point B. The journey can be represented pictorially by the vector diagram shown. Each of the two displacements is represented in magnitude and direction by a vector. These vectors are placed tip to tail to represent the complete journey.

What is the total displacement (magnitude and direction) for the whole journey? (Remember that displacement is "change in position" not "distance travelled".)

ANS..........

Draw on the diagram a single vector representing the total displacement from the starting point O.

DON’T CHECK YOUR ANSWER TO THIS QUESTION YET

2

(a) Consider a journey comprising two displacements, firstly 5 km North East followed by 5 km South East. What is the total displacement (magnitude and direction) for the journey?

ANS........

Draw a vector diagram

representing the two

displacements and their sum.

DON’T CHECK YOUR ANSWER TO THIS QUESTION YET

(b) Consider now a journey comprising two displacements, the first being 5 km South East followed by 5 km North East. What is the total displacement (magnitude and direction) for the journey?

ANS........

Draw a vector diagram

representing the two

displacements and their sum.

CHECK YOUR ANSWER TO THIS LAST GROUP OF QUESTIONS

1



2

The total displacement is approximately 2.8 km in a North‑Easterly direction.

The total effect of the two displacements O to A and A to B is a single displacement from O to B. This is represented by the vector labelled S. This represents the vector sum of the two displacement vectors. It represents the "change in position" not "the distance travelled". The length of the vector S (from Pythagoras Theorem) is √8 ≈ 2.83 km and it is in the North‑East direction.

This simple example illustrates the rule for adding vectors. Arrange the vectors tip-to-tail and join the tail of the first to the tip of the last.

2

(a)



3

The displacement is approximately 7.1 km in an Easterly direction. This is represented by the vector S whose length is √50 ≈ 7.07 km and is pointing East.

(b)



4

The displacement is approximately 7.1 km in an Easterly direction. This is represented by the vector S whose length is √50 ≈ 7.07 km and is pointing East.

The answers are the same as for part (a). It does not matter in which order the vectors are added. This is a general rule for adding vectors. Also we usually define vectors without specifying where either end is located.

3



5

The diagram shows two vectors A and B.

(a) Draw the vector -B.

(b) Using the "tip to tail" method construct the vector A+(‑B).

This is more simply written A-B.

(c) Draw the vector -A.

(d) Construct the vector B-A.

CHECK YOUR ANSWERS TO THIS QUESTION

4



6

The diagram shows three vectors A, B and C.

(a) Construct the vector A+B and then add to this vector the vector C. The resultant vector is A+B+C.

(b) Construct the vector A+C and then add to this vector the vector B. The resultant vector is A+C+B.

CHECK YOUR ANSWERS TO THIS QUESTION

3



7

(a) The vector -B is of the same length as B but in the opposite direction

(b) The "tip to tail" method is used to add vector -B to the vector A to give the vector A+(‑B) which is simply written A-B.

(c) The vector -A is equal in length but opposite in direction to vector A.

(d) The vector B-A is simply the sum of vector B and vector ‑A. Note that this vector is equal and opposite to the vector A-B constructed in question (b).

That is, the rule B-A = -(A-B) is true for vectors.

4



8

(a) The vector A+B is constructed first and then vector C is added to form vector A+B+C.

(b) Here the vector A+C is constructed first and then vector B is added to form vector A+C+B. Note that this vector is the same as the vector A+B+C.

5



9

The diagram shows three vectors A, B and C.

Construct the vector A+B+C.

What is the magnitude of the resultant vector A+B+C?

CHECK YOUR ANSWER TO THIS QUESTION

6

Forces, like displacements, have a magnitude and direction and it is not surprising that they obey the same laws of addition.



10

Consider a heavy block being pulled by ropes attached to two tractors. Each exerts the same force which we will specify as 2 ton weight. One is pulling in a northerly direction and the other in an easterly direction. Draw a vector diagram corresponding to this situation and use it to find a single force on the block which is equivalent to the two separate forces.

CHECK YOUR ANSWERS TO THIS QUESTION

5



11

The three vectors form a closed triangle. The magnitude of the resultant vector (the distance between the tail of A and the tip of C) is zero. It is a general rule that if the vectors arranged tip to tail form a closed figure then their sum is zero.

6



12

The equivalent force, the so-called "resultant force", on the block is of magnitude approximately 2.8 ton weight and is in the North-East direction. Note that this vector diagram is the same as that in the answer to Question 1. Both forces and displacements, and many other quantities as well, obey the laws of vector addition.

In many cases you will be concerned with adding up forces and using this knowledge to calculate how a body will move. The simplest case is where a body is acted on by a set of forces but remains stationary. In this case the sum of the forces will be zero

7



13

Consider now three tractors pulling on a heavy block. One is pulling with a force of 3 ton weight in a northerly direction and another is pulling with a force of 4 ton weight in an Easterly direction. The third tractor is pulling with such a force as to counteract the forces exerted by the other two.

Draw a vector diagram to determine the resultant of the 3 and 4 ton weight forces.

Calculate the magnitude and direction of this resultant

ANS......

What is the magnitude and direction of the Force exerted by the third tractor?

ANS.....

CHECK YOUR ANSWERS TO THIS QUESTION

The previous questions have shown how two or more vectors can be added to produce a single resultant vector. The following questions will show how a single vector can be broken down into two component vectors.

8



14

The vector C is of length 4.3 units. Draw two vectors, A parallel to Ox, and B parallel to Oy such that C = A+B.

What is the length of vector A?

ANS......

What is the length of vector B?

ANS......

CHECK YOUR ANSWERS TO THIS QUESTION

7



15

5 ton weight in the direction 53o East of North.

The resultant of the forces exerted by the first two tractors is shown in the diagram. the magnitude of the force is 5 ton weight and its direction is 53o East of North. This can be calculated using trigonometry or by measurement from an accurate drawing.

Since the force exerted by the third tractor must counterbalance this force it must be of magnitude 5 ton weight in the direction 53o West of South.

8



16

The vectors A and B are drawn tip to tail so that their sum is equal to the vector C.

The lengths of A and B can be read directly from the squared paper.

Length of A = 3.5 units

Length of B = 2.5 units

A and B are called component vectors.

A is the component vector of C parallel to ox and B is the component vector of C parallel to oy.

The vector C can be described by saying:

"The component of C in the direction ox is 3.5 units and the component of C in the direction oy is 2.5 units."

This is a very common and useful way of describing vectors particularly when dealing with forces acting on a body.

9

w184



17

The vector C is of length 5 units. Answer the following questions first by calculation and then checking with direct measurement.

(a) What is the component of C in the direction Ox?

ANS

(b) What is the component of C in the direction Oy?

ANS

(c) What is the component of C in the direction Ox'?

ANS

(d) What is the component of C in the direction oy'?

ANS

CHECK YOUR ANSWERS TO THIS QUESTION

Now that you have knowledge of vectors you are now in a position to be able to understand how forces are added together.

This group of questions is to test your understanding of forces in familiar situations. The most primitive idea of Force is a push or a pull and we can develop our ideas from this simple notion.

In the following questions you are asked to draw force vectors to represent the forces acting on bodies in various situations. Answers given for the first two questions will guide you in answering subsequent questions.

10



18

Draw vectors to represent the forces which are acting on a heavy ball which is resting on a coil spring. Describe the nature of the forces.

CHECK YOUR ANSWER TO THIS QUESTION.

11

Draw vectors to represent the forces which are acting on a heavy ball which is resting the floor. Describe the nature of the forces.

CHECK YOUR ANSWER TO THIS QUESTION.

9



19

(a) Component of C in direction Ox

= 5 cos 37o = 4 units

(a) Component of C in direction Oy

= 5 sin 37o = 3 units

(a) Component of C in direction Ox'

= 5 cos 60o = 2.5 units

(a) Component of C in direction Oy'

= 5 sin 60o = 4.3 units

10

The vector W represents the gravitational force on the ball



20

(its weight) and S represents the force exerted on the ball

by the compressed spring.

The force S exerted by the compressed spring is familiar to anyone who has squashed an elastic body such as a tennis ball. In the case illustrated this force is directed upwards. It is for simplicity shown acting through the centre of the ball. The weight force W is the force of attraction between the ball and the Earth and is directed towards the centre of the Earth (downwards). These two forces are equal and opposite. There is no unbalanced force on the ball. You will learn later that when a body is at rest (or travelling with constant velocity) there is no unbalanced force acting on the body.

11



21

The vector W represents the gravitational force on the ball

(its weight) and R represents the "normal reaction force" exerted on the ball by the floor. Note that in this case the word "normal" means "perpendicular" not "usual".

Students sometimes have difficulty in understanding how the floor could exert a force on the ball. This force is in fact similar to the spring force in the previous question. The floor is not perfectly rigid. It will squash down slightly because of the weight of the ball and behave in the same way as a spring. Reaction forces always arise when bodies are pressed into contact and in simple cases these are directed perpendicular to the surfaces which are in contact. Since the ball is stationary, R and W must be equal in magnitude and opposite in direction.

For each of the following questions (12 to 23)draw vectors to represent the forces which are acting on the object and describe the nature of the forces.



22

12 A block sliding down a smooth (frictionless) plane.

13 A block sitting at rest on a rough (frictional) inclined plane



23

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14 A mass hanging at rest on the end of a spring



24

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15 A mass on the end of a stretched spring just after being released.



25



26

16 A mass hanging at rest on the end of a string.

CHECK YOUR ANSWERS TO THIS GROUP OF QUESTIONS

12



27

Here the weight force W is directed vertically down but the normal reaction force R is perpendicular to the inclined plane (Remember that "normal" means "perpendicular").

In this case the forces cannot cancel (the sum of the two vectors cannot be zero). There is an unbalanced force and as you will learn later this causes the body to accelerate down the slope.

13



28

In addition to the weight and the normal reaction force there is a friction force acting on the body directed up the slope. Because the body is at rest these three forces must balance. Remembering what you have learnt about summing vectors by arranging them tip to tail you can see that the three vectors must form a closed triangle.

It is worth noting that with a smaller frictional force the forces would not balance (the vectors would not form a closed triangle) and the block would accelerate down the slope. You will learn later how to calculate the resulting acceleration from the unbalanced force.

14



29

This is a very similar situation to that of question 10. Here the extended spring is exerting an upward pull on the ball. This force S is equal and opposite to the weight force W since the mass is at rest and there can therefore be no unbalanced force on it.

15



30

Here the spring is stretched more than in the previous question and the force S is greater than W. There is therefore an unbalanced force and the mass is accelerated upwards.

16



31

This is the same situation as in question 14. The string will extend very slightly and act in the same way as a spring exerting an upwards force, usually called a tension force T. This must be equal and opposite to the weight force W since the body is at rest and therefore the forces must be balanced.

17



32

A sled being pulled by a rope across a smooth (frictionless) ice surface.

18



33

A sled being pulled across a rough (frictional) surface.

19



34

A ball in flight after being thrown vertically upwards. (Assume that there is no friction force due to the atmosphere.)

20



35

A ball falling vertically downwards. (Assume that there is no friction force due to the atmosphere.)

CHECK YOUR ANSWERS TO THIS GROUP OF QUESTIONS

17



36

In addition to the forces W and R there is also a tension force T transmitted by the rope. In this case the forces cannot balance and there is a resultant unbalanced force which causes the sled to accelerate across the ice.

R will in this case be less than W. Remember what you learnt about components of vectors. Since the sled is not moving vertically the upwards vertical force acting on it (the sum of R and the vertical component of T) must be balanced by the downwards force W.

The horizontal component of T is the only horizontal force acting and this will cause the sled to accelerate across the ice.

18THERE MAY BE ANOTHER FIGURE (W162?) TO GO HERE



1

In addition to W,R and T there is a frictional force F pulling backwards on the sled. There is one special value of T for which the horizontal forces balance and in this case the sled would move with constant velocity across the surface. For higher values of T the sled would accelerate. This will become clear after you study Newton's Laws of Motion.



37

19

The only force acting on the ball is the weight force. The ball has left the thrower's hand so there is no force associated with the initial throwing. Under the influence of this unbalanced weight force the ball will suffer a downwards acceleration.

20



38

Again the only force acting is the weight force W. Under the influence of this unbalanced weight force the ball will suffer a downwards acceleration.

21



39

An artillery shell at various positions along its path after being fired from a gun. Mark in the forces for each position of the shell. (Assume that there is no friction force due to the atmosphere.)

22



40

A mass swinging "pendulum fashion" on the end of a string at each of the 5 positions shown, the two extreme positions, the lowest point and two intermediate positions.

23



41

A ball moving from left to right bounces as shown. Mark vector arrows on the diagram representing any force (including friction due to air resistance) acting on the ball at position A and at position B. Label each vector with a name describing the force.

CHECK YOUR ANSWERS TO THIS GROUP OF QUESTIONS

21



42

Here again the only force acting is the weight force W. You may have marked in a force vector in the direction of motion of the shell. If so, you have fallen in to a common trap of thinking that a force is required to "keep a body moving". This is a common error which arises because of the presence of friction in everyday situations. Normally we have to apply a force to overcome friction and keep objects moving. In the absence of friction however, a body would continue moving with uniform speed when no forces were acting on it. If a force were imposed it would accelerate. The nearest thing to frictionless motion which you might experience is motion of bodies on ice or on an air-track in your school laboratory.

REMEMBER THAT A FORCE IS NOT NEEDED TO CAUSE MOTION. FORCES ARE NEEDED ONLY TO CHANGE MOTION.

22



43

For each position there are two forces acting on the body:

i) the weight force which is vertically down and has the same value at each position and

ii) the tension force T which is directed along the line of the string which will vary from position to position. (It will in fact be greatest at the midway position and least at the extreme positions.)

These forces do not balance at any of the five positions and the unbalanced force give rise to an acceleration (a change in velocity) of the body. Note that at all positions the mass is accelerating since its velocity vector (magnitude and direction) is changing.

Note also that there is no additional force in the direction of motion. A force is not (in the absence of friction) required to cause motion.

Later you will learn how to calculate the motion of the pendulum in terms of these forces.

23



44

The only forces acting are the weight force due to the gravitational attraction of the Earth and a Friction force due to air resistance. The weight force always acts vertically downwards and the friction force is in the opposite direction to the motion of the ball. There is NO force in the direction of motion. A force is not necessary to cause motion. The effect of a force is to change motion.

COMMENTS