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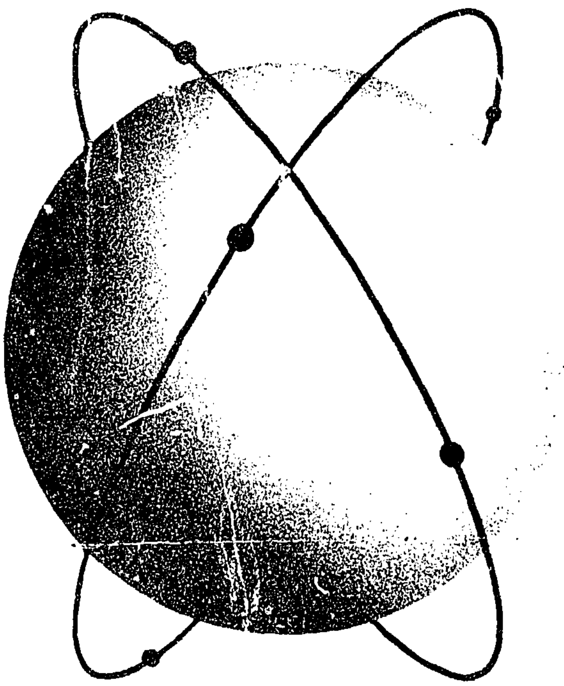
ABSTRACT

As the seventh lesson of the Articulated Multimedia Physics Course, instructional materials are presented in this study guide with relation to the force combination. The topics are concerned with the definition and units of forces, sliding forces on inclined planes, and the equilibrant of two or more forces. The content is arranged in scrambled form, and the use of matrix transparencies is required for students to control their learning activities. Students are asked to use magnetic tape playback, instructional tapes, and single concept films at the appropriate place in conjunction with the worksheet. Included are a homework problem set, a study guide slipsheet, and illustrations for explanation purposes. Related documents are SE 015 963 through SE 015 977. (CC)

ARTICULATED MULTIMEDIA PHYSICS



LESSON 7

NEW YORK INSTITUTE OF TECHNOLOGY
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ARTICULATED MULTIMEDIA PHYSICS

Lesson Number 7

COMBINING FORCES

IMPORTANT: Your attention is again called to the fact that this is not an ordinary book. It's pages are scrambled in such a way that it cannot be read or studied by turning the pages in the ordinary sequence. To serve properly as the guiding element in the Articulated Multimedia Physics Course, this Study Guide must be used in conjunction with a Program Control equipped with the appropriate matrix transparency for this Lesson. In addition, every Lesson requires the availability of a magnetic tape playback and the appropriate cartridge of instructional tape to be used, as signaled by the Study Guide, in conjunction with the Worksheets that appear in the blue appendix section at the end of the book. Many of the lesson Study Guides also call for viewing a single concept film at an indicated place in the work. These films are individually viewed by the student using a special projector and screen; arrangements are made and instructions are given for synchronizing the tape playback and the film in each case.

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New York Institute of Technology
Articulated Multimedia Physics

LESSON 7

STUDY GUIDE SLIP SHEET

STUDY GUIDE TEXT: No changes.

STUDY GUIDE DIAGRAMS: No changes.

WORKSHEETS: Question 1, which appears on the Worksheet for Tape Segment 1. Some of these terms may be unfamiliar to you. Don't hesitate to use a dictionary to settle your doubts.

HOMEWORK PROBLEMS: Let's amplify this a bit. It is assumed that the rope does not stretch but that the car moves as a result of the force applied to the midpoint of the rope. The pulling force you are to find is the force that exists after the midpoint of the rope has been pulled aside by 3.0 ft. At that point, consider the system to be in equilibrium.

One can seldom move into any of the realms of physics without running headlong into force and forces. The concept of force pervades the whole structure of basic science; you find it everywhere.

Force is not a new word to you. We have mentioned it now and again in connection with gravity and weight. We have spoken of the force of gravitation as that action or phenomenon which lends weight to a body. You will probably remember that we tentatively defined force as a push or a pull, and that we promised to present a more sophisticated definition of it when the proper time came.

In addition to gravitation and its effects, there are many other kinds of forces: your muscles enable you to exert force; the combustion of gasoline in your car accounts for the force that the engine can exert on the wheels; the electricity in a vacuum cleaner or pump is converted into mechanical force; magnets can exert forces on materials like iron and on each other; and on and on. But regardless of the source, all forces have certain common characteristics which permit us to predict and account for their effects. Once you learn how to combine and break down simple mechanical forces, you can apply the very same methods to muscular, chemical, electrical, and magnetic forces, as well as any others you may encounter. This technique, of course, is one of the basic building blocks of physics: we develop generalizations which then can be specifically applied in principle to new situations and events.

Please go on to page 2.

Once we decide on a certain unit of measure for force in mechanics, the same unit can be used for any other kind of force. As in the measurement of mass and displacement, we again have a choice of English and metric units; it makes little difference in our understanding which units we use, but we must be consistent within any given problem. There is nothing new in this idea either. Despite the fact that MKS units are preferable in most phases of physics, we shall not be able to use them in this lesson. The reason for this is easily given: you have already developed a "feeling" for the meaning of a pound (lb) of force because you live in a community where the lb is common in all weight measurements. You know that the force of gravitation acting on a 5 lb bag of sugar is 5 lb; you know that the force of gravitation acting on you is, say, 125 lb if this is your weight

In the MKS system, the force unit is the <u>newton</u>; in another metric system (the CGS) the force unit is the <u>dyne</u>. At this point in your learning, it would be meaningless to introduce these new units. So for this lesson we shall stick to the lb and its derivatives like the ounce (oz) and the ton (t). Later, you will discover the significance and convenience of the MKS unit of force; then, we will endeavor to build up the same kind of "feeling" for these units as you have for the lb and ton. Once this has been done, we shall abandon the English system almost completely.

Please go on to page 3.

This lesson is entitled "Combining Forces." Before you start to work on it, we strongly urge you to review vector addition for both collinear vectors and vectors acting at angles. Unless you do this conscientiously, you will find that we will often refer to things which you should know but which you may have forgotten. Again, familiarize yourself with the graphical method of adding vectors and resolving them into components; go over your notes on vector triangles, especially those involving the Pythagorean theorem. We expect you to know the language and techniques quite well, so take whatever time you need to refresh your memory thoroughly.

When you have completed your review, please turn to page 164 in the blue appendix.

As human beings living in a universe of motion, we are often inclined to associate force with motion. This is a natural line of thought and may be quite justified by your daily experiences. As you write, you exert a force on your pencil and it moves about to produce script; as you breathe, the muscles of your diaphragm exert force on the air in your lungs and the air moves; as you chew your food, your jaw muscles act on the food (through the medium of your teeth, of course) and the food moves from the outside to the inside.

So force and motion appear to be closely involved.

Suppose you close a door by pushing on one of the wood panels. You exert a force because you push, and the door responds by closing.

Next, suppose that you pull on the doorknob of a closed door but, because you failed to turn the knob to release the latch, the door remains closed despite your efforts.

Since the door did not move as a result of your efforts, did you exert a force on it?

(1)

A Yes.

B No.

YOUR ANSWER --- C

You are correct.

Certainly the force of 5 lb is large enough to close the door, but it might be exerted in the wrong direction. If you are standing in front of the door and a pull of 5 lb will close it, then a push of 5 lb at the same point will cause the door to open farther.

Clearly, then, if you want to describe a force completely, you must give its magnitude and its direction. We met the same requirements when we discussed displacements and velocities, and you remember that we had to treat these ideas with a great deal of care. We saw that the omission of direction in our specifications could easily lead to the wrong answer.

From the foregoing example, and from many others you can invent for yourself, which of the following is obviously true about force:

(3)

A It is always a scalar quantity.

B It is always a vector quantity.

C It is sometimes a scalar and sometimes a vector quantity, depending on the particular situation in which it appears.

CORRECT ANSWER: The angle between the dotted extension of vector A and vector B should be 60°.

By making the angle between the dotted extension of vector A and vector B equal to 60°, you show the angle between the forces as it should be.

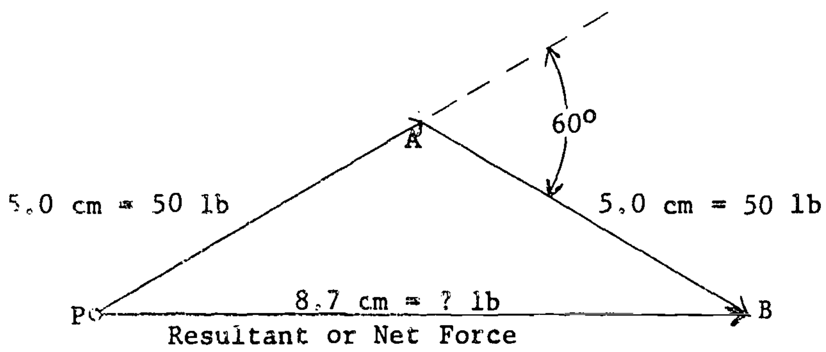


Figure 7

Refer to Figure 7.

Step 3. When the two component vectors, A and B, have been laid out to scale, and at the proper angle, the line segment representing the resultant force may then be drawn in the usual way: from the tail of the first arrow to the head of the second.

Step 4. Place the arrowhead at the right-hand end, and measure the length of the resultant line segment in centimeters. According to our measurements, this resultant length is 8.7 cm, to 2 significant figures.

Step 5. Finally, convert the length of the net force vector in centimeters to the correct force unit using your scale.

Thus, if the net force length is 8.7 cm, what is the resultant force acting on point P of the sled?

Write your answer. Turn to page 15.

YOUR ANSWER --- A

This answer is too small.

Check the following to help you locate your source of error:

(1) Your pencil may be too soft or too dull. Use a medium-hard sharply-pointed pencil. We're not being fussy just for the sake of being fussy! A blunt pencil can cause an appreciable error.

(2) Measure your vector line segments again according to scale. We're using 1 cm = 20 lb; hence the 120-lb force should be 6.0 cm long and the 80-lb force should be 4.0 cm long.

(3) Measure the angle between the extension of the 120-lb force and the 80-lb force vector. This angle should be 80.0 degrees, on the nose.

(4) Look at the resultant vector you drew. Does it really join the ends of the other vectors or does it miss a little at either end? Your aim should be as perfect as possible.

(5) Measure the resultant vector again, reading to the nearest tenth of a centimeter. Thus, if you took it as 7 cm or 8 cm, rather than 7.1 cm or 8.3 cm, you weren't reading your scale accurately enough.

(6) Multiply the resultant scale reading by 20 and round off to 2 significant figures.

Now return to page 109 please. Select a better answer.

YOUR ANSWER --- B

Refer to Figure 2 on page 112. Initially, the particle has a uniform velocity of 50 mi/hr in the direction of the heavy arrow. Examining the forces, we see that the two 5-lb forces are equal in magnitude and opposite in direction. As we saw, these do not change the motion of the particle. The other two forces are also balanced in the same sense; hence they do not contribute to the motion in any way.

Therefore, the particle continues to move with unchanged velocity and may be said to be in equilibrium.

But is this static or dynamic equilibrium?

Turn to page 14 to check your thinking on this question.

YOUR ANSWER --- B

Review your notes on vector addition. This is not correct.

Return to page 89 after reviewing your notes, please. You will then be able to select the right answer.

YOUR ANSWER --- A

You are correct. A force is defined as a push or a pull, whether or not it produces motion. The fact that forces usually produce motion in your daily experiences does not mean that a force must always produce motion.

A force is frequently applied to prevent motion. When your car is standing on an incline, you set the parking brake to insure that the car will not roll down the hill. The brake applies a force to the wheels that prevents motion.

NOTEBOOK ENTRY
Lesson 7

1. Definition of a force
   (a) A force is a push or a pull.
   (b) A force may cause or prevent motion, or have the tendency to do so.

The door of your study now stands partly open. Say that it is well-oiled at the hinges so that a force of only one lb is needed to move it. You walk over to it and exert a force of 5 lb on it. Will the door close?

(2)

A Yes.

B No.

C Maybe.

YOUR ANSWER --- D

To show why your answer selection is incorrect, we shall prove that one part of it is unacceptable. (This does not mean that the other one is necessarily correct. It may or may not be.)

Refer to Figure 4A on page 113. Your answer states that this Figure is wrong, which is not true. A is correct. Let's assign a (+) sign to the easterly direction; thus we have:

Net force = (+20 lb) + (+30 lb) + (-20 lb)
= +30 lb to the E.

So A is correct and your answer is wrong.

Please return to page 113 and make another choice.

YOUR ANSWER --- C

<u>This answer is too large.</u>

You may be able to locate your source of error if you go over the following items one by one:

(1) Is your pencil medium-hard and very sharp? If it isn't, it may be responsible for an appreciable error. This is a fact; we are not being overly fussy.

(2) According to our scale: 1 cm = 20 lb. Measure your vector line segments to be sure that the 120-lb force vector is 6.0 cm long and the 80-lb force vector is 4.0 cm long.

(3) Check the angle between the extension of the 120-lb force vector and the 80-lb force vector. It should be 80.0 degrees, not 80.1 or 79.9 degrees.

(4) Examine the resultant vector you drew; this is supposed to join the ends of the component vectors. Does it really meet the other two vectors at their <u>exact</u> ends? Or does it miss the mark a bit on either or both sides? <u>Improve your aim!</u>

(5) <u>Measure</u> the resultant vector again. You must read it to the nearest <u>tenth</u> of a centimeter or to the nearest millimeter.

(6) Multiply the resultant length by 20 and round off to 2 significant figures.

Please return to page 109. Choose another answer.

CORRECT ANSWER: The equilibrant has a magnitude of 12 lb and is directed toward the SE.

Thus, an equilibrant may be defined as a single force which maintains a particle in equilibrium despite the action of other forces on the same particle.

Before making a notebook entry on this, we want one more important bit of information regarding the equilibrant. Since you had no trouble in determining the magnitude and direction of the equilibrant in Figure 9 on page 34, it must be closely related to the other forces acting on P.

Just what is this relationship? Which one of the following statements best describes the equilibrant fully?

(17)

A The equilibrant is equal to the resultant of A and B.

B The equilibrant is equal in magnitude and opposite in direction to the resultant of A and B.

C The equilibrant is equal to the sum of the component forces, A + B.

D The equilibrant is equal to the vector difference of the component forces, A - B.

CORRECT ANSWER: The particle in Figure 2 on page 112 is in <u>dynamic</u> equilibrium.

A body cannot be said to be in <u>static</u> equilibrium if it is in motion. This is true regardless of the kind of motion or the magnitudes and directions of the forces acting on it.

If a particle is moving with uniform velocity initially, it may be said to be in <u>dynamic</u> equilibrium. Should forces then be applied in such a way as to leave the velocity unaffected, the particle will continue in the state of dynamic equilibrium.

Turn to page 73 to go to the correct answer page of the original question.

CORRECT ANSWER: The net force is 87 lb if the length of the resultant vector is 8.7 cm.

Refer to Figure 7 on page 6. From the scale: 1.0 cm = 10 lb, we find that 8.7 cm = 87 lb.

So the magnitude of the net force is 87 lb, and its direction is that shown by the resultant vector arrow. If you wished to express this direction in degrees, you might say that the net force vector makes an angle of 30° with force A vector, in a clockwise direction.

Now you will want to solve a typical problem in composition of forces, as this technique is called. Write it out step-by-step on scrap paper; it will later be transcribed into your notebook as an example. You will be expected to work with 2 significant figures.

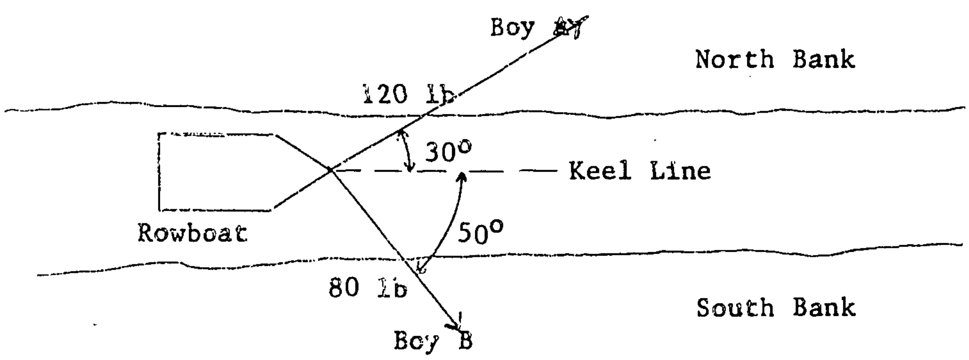


Figure 8

Refer to Figure 8. Two boys, one on each side of a stream, pull a rowboat upstream by means of ropes tied to its bow. In the drawing, the keel-line of the boat is shown as a broken line. One rope makes an angle of 30° with the keel-line and the other an angle of 50° with the keel-line. Boy A pulls with a force of 120 lb along his rope; boy B pulls with a force of 80 lb along his rope.

What is the angle between the taut ropes? Turn to page 39.

YOUR ANSWER --- B

This is incorrect on <u>both</u> counts.

Group 2 cannot be entirely correct because it has at least one error (possibly more!) as follows:

> A force of 1.9 lb north acting on the same point as a force of 7.1 lb north would produce a resultant of 9.0 lb north. The equilibrant must have the same magnitude but opposite direction. Hence the equilibrant is 9.0 lb south. The answer given is 9.0 lb north; the direction is wrong.

Group 1 cannot be all wrong because it has at least one correct answer (possibly more!) as follows:

> A force of 5.0 lb west acting on the same point as a force of 3.0 lb west would produce a resultant of 8.0 lb west. The equilibrant must have the same magnitude but opplsite direction. Hence the equilibrant is 8.0 lb east. This is the answer given.

Please return to page 131. Remember, we want you to select one horizontal row in which both descriptions fit the facts.

YOUR ANSWER --- B

Well, the force of 5 lb is certainly large enough to close the door considering that even a one-lb force will do the job. Why, then, do you say that the door will not close?

If, in your mind, you visualized yourself exerting a 5-lb force on the door in the wrong direction, then your answer is right. If a door opens inward into a room and you exert a 5-lb inward force on it, the door will not close; it will open farther.

But the original question did not indicate the direction in which the force was exerted; therefore you had no right to assume that its direction would not be right to cause closing.

In short, your error lies in the fact that you made an assumption that you had no right to make, since it was not explicitly stated in the description of the situation.

Please return to page 10 and choose a better answer.

YOUR ANSWER --- B

Quite right! The direction and magnitude of a force must always be given if you want to analyze its action.

NOTEBOOK ENTRY
Lesson 7

(Item 1)

(c) Force is a vector quantity. To describe a force completely, both magnitude and direction must be specified.

In the early days of physics, the philosophers who represented the scientists of that time could not visualize any way that a force could be applied to a body without contact between the source of the force and the body. That is, to push or pull something you had to touch it. Unless you are a magician, you can't bring your pencil to you from the desk by wishing it into your hand, or by whistling at it. You have to reach out for it, make contact with it, and then push or pull it toward you.

Everyone has played with magnets enough to know that a nail can be drawn to a strong magnet without contact. Merely bringing the magnet close to the nail will cause the pull of the magnet to act on the nail and drag it along. But the early philosophers could not explain forces acting at a distance because they could not imagine how a force might act without some kind of contact.

Which one of the following involves a forve that acts over a distance?

(4)

A Pulling a sled by means of a rope.

B Gravitation causing a stone to fall from a cliff.

C A wind causing a sailboat to move.

YOUR ANSWER --- C

Refer to Figure 3 on page 78. You omitted one of the forces in your calculation. You evidently accounted for forces A and B, but forgot to include force C in your algebra. If only forces A and B were applied to P, then the net force would be: A + B = (-3 lb) + (+2 lb) = -1 lb, and since the (-) direction is SW, then the answer is 1 lb to the SW.

But force C is also acting on P and will surely affect the final value of the net force, will it not?

Recalculate, taking force C into account.

Then turn to page 69 and pick the right answer.

YOUR ANSWER --- A

Refer to Figure 12 on page 148. The length of the line segment PC that represents the equilibrant is 7.1 cm. But this is only a representation of the actual force. To determine the magnitude of the force itself you must convert the 7.1 cm-length to pounds.

Please return to page 148 and choose the other answer.

YOUR ANSWER --- A

No, that's not right. Look at Figure 11 on page 44 again. A resultant of two or more forces is a single force that could replace the original forces and produce exactly the same effect. Well, now, the two original forces would cause the sled to move to the <u>right</u>, wouldn't they? Hence, a single force that could replace A and B would have to be directed toward the right and would have to have a magnitude such that the sled would move at the same speed as a result of this new force as it did when A and B were applied, separately.

But force C is directed toward the <u>left</u>. Regardless of its magnitude, it could never do the same thing as A and B can do in combination. This means that C cannot possibly be the resultant of A and B.

Please return to page 44 and choose the other response.

YOUR ANSWER --- B

If force B is taken as the equilibrant for A and W, then you could say that the resultant of A and W is a force of the same magnitude as the equilibrant you chose, force B, but opposite in direction.

But you don't want the resultant of A and W, do you? You're interested in finding the resultant of A and B, according to the question.

This indicates quite clearly that you selected the wrong force to designate as the equilibrant of the system.

Please return to page 135 and select a better answer.

YOUR ANSWER --- C

You are perfectly correct. See Figure 17.

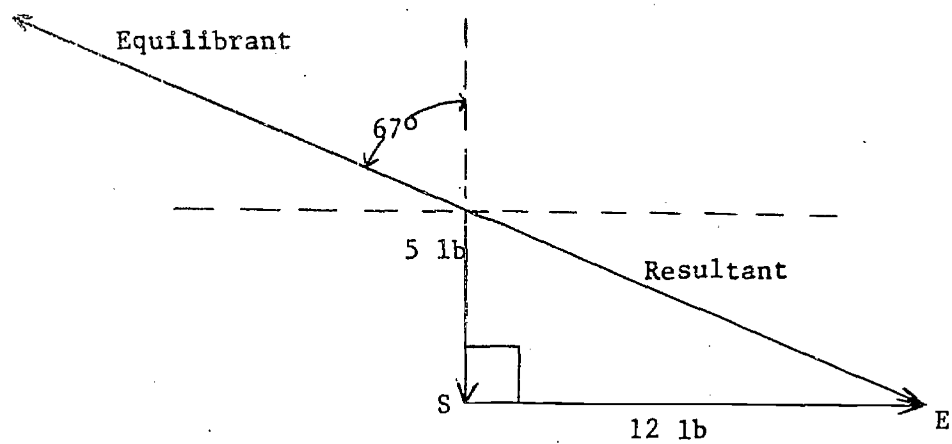


Figure 17.

Except for a possible difference of scale, your diagram, if you drew one, should look like this one. You didn't need it if you used the Pythagorean theorem or recognized the 5:12:13 triangle. To obtain the exact angle, either you need to know trigonometry, or you must set up a diagram to scale.

Let's see how you can handle one or two questions on this subject without using calculations.

Imagine a particle acted on by a large force, say 100 lb north, and a very small force at right angles, say 2.0 lb east.

What would the resultant look like?

(28)

A The resultant would be much larger than 100 lb.

B The resultant would be just a bit larger than 100 lb.

C The resultant would be just a bit larger than 0.5 lb.

CORRECT ANSWER: Forces F_1 and F_2 shown in example D are the rectangular components that constitute the resultant R.

Components are considered rectangular when they act at 90° to each other. In elementary physics, we confine ourselves to rectangular components because most situations involving forces that act on the same particle are best handled in a rectangular frame of reference.

Figure 22 is a pictorial diagram of a boy pulling on a sled by means of a rope. This is a side view. Now, because of the slant of the rope and the fact that the only possible kind of pull on the rope must act along the rope in the same line, the force exerted by the boy must have two independent effects: (1) part of his force pulls the sled forward and (2) part of his force tends to lift the front of the sled off the ground. Our major concern at this moment is to determine the useful component of his pull on the rope.

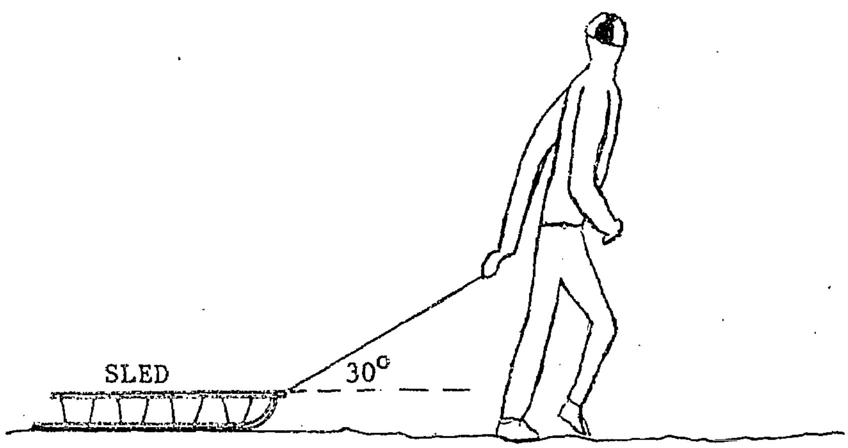


Figure 22

Which of the two parts of his force would you consider the useful component?

(31)

A The component of his force that acts forward.

B The component of his force that acts upward.

YOUR ANSWER --- A

This answer choice is a sign that you have not reviewed your work on vector addition as we suggested in the introduction to this lesson.

Refer to Figure 5 on page 134. To obtain the net force (100 lb) you added the magnitudes of the two components algebraically after assigning (+) directions to each.

THIS PROCEDURE CANNOT BE USED IN ADDING VECTORS AT ANGLES OTHER THAN 0^o OR 180^o. Clearly, the two ropes in Figure 5 do not form either of these two angles.

What kind of forces do form either 0^o or 180^o angles between them?

(13)

A Forces that produce equilibrium.

B Collinear forces.

YOUR ANSWER --- A

Your choice of answer is incorrect.

Either you selected choice "A" by mistake, or you have forgotten the difference between a scalar and a vector quantity.

In describing a scalar quantity, only magnitude is required.

In describing a vector quantity, both magnitude and direction must be specified.

We have seen that failure to specify the direction of a force may lead to an ambiguous picture and to the wrong conclusion.

Please return to page 5 and pick a better answer.

YOUR ANSWER --- B

Of course, it is always possible that spring balances may be inaccurate and in need of adjustment or repair. But even if these balances were perfect, the sum of their readings would not equal the hanging weight. Why?

Balance A, for example, is exerting its force along the line of the slanted string connecting A to P. Although the force produced by its stretched spring is mostly upward, some of it is wasted in pulling the string to the left. So, only a part of the force of 4.2 lb is exerting in a general upward direction supporting the weight. The same reasoning may be applied to balance B; only a part of the 2.0 lb exerted by its spring is being utilized to keep the weight in equilibrium.

Whenever forces act at angles this way, it will be found that the algebraic sum of the angled forces is greater than you might expect on first thoughts.

For only one set of circumstances would the sum of the balance readings equal the hanging weight. When would this happen?

(23)

A If the balances were arranged to exert their forces collinearly.

B If the forces exerted by the balances were equal to each other.

YOUR ANSWER --- C

This is incorrect on both counts.

Group 3 cannot be entirely correct because it has at least one error (possibly more!) as follows:

> An 8.7-lb force acting west added to another 8.7-lb force acting west on the same point would yield a resultant of 17.4 lb west. The equilibrant must have the same magnitude as the resultant, although its direction is opposite. However, the answer given is 0.0 lb which is certainly not the same magnitude as 17.4 lb, nor is it directed oppositely.

Group 4 cannot be all wrong because it has at least one correct answer (possibly more!) as follows:

> Two forces, one of 83.8 lb north and the other of 92.0 lb south have a resultant of 8.2 lb south. The equilibrant must have the same magnitude but opposite direction; hence the equilibrant must be 8.2 lb north. This is the answer given.

Please return to page 131. Remember, you are to choose one horizontal row in which both descriptions fit the facts.

YOUR ANSWER --- D

This answer is quite incorrect. You should remember that in the case of collinear forces a vector difference is found by reversing the sign of the subtractor and then adding algebraically. Well, if you perform the vector subtraction correctly you get (+8 lb) + (-4 lb) = 8 lb - 4 lb = 4 lb.

The vector difference, then, gives you an answer of 4 lb to the NW. Could such a force added to A and B possibly produce equilibrium of particle P? No, it couldn't.

But, by definition, an equilibrant is a single force which maintains a particle in equilibrium despite the action of other forces on the same particle. Hence, you can't describe the equilibrant as you did in the answer you selected.

Please return to page 13. Go back to the original question and pick a more plausible answer.

YOUR ANSWER --- A

This answer is a "natural" one, yet it is incorrect. There is nothing "special" about the force exerted by W as compared with the forces exerted by A and B, yet students seem to feel that, because W acts straight downward, it has some kind of peculiar properties.

Any force may be considered as the equilibrant of a system of forces <u>if this force maintains equilibrium of the particle despite the action of other forces on it</u>. Consider force A. Suppose you cut string AP. Wouldn't the particle suddenly shift downward and to the right until it again came to rest immediately under B? Therefore, doesn't force A serve to keep the particle in equilibrium against the pulls of B and W? We must conclude from this that A <u>may</u> be considered as the equilibrant in the system containing A, B, and W. A similar argument shows that force B <u>or</u> force W may be taken as the equilibrant of the system.

Please return to page 153. You can now confidently choose the alternative answer.

YOUR ANSWER --- A

You are correct. Figure 19 illustrates three widely different sets of conditions, yet in each case angle 1 = angle 2 because the initial forces are equal in magnitudes.

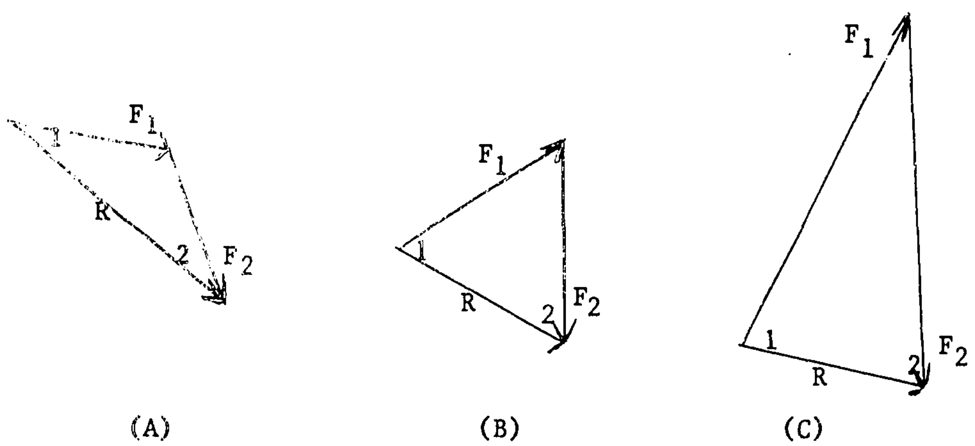


Figure 19

Suppose two forces of any magnitude act on a single particle at an angle of 20° to each other. What would happen to the resultant of these forces if the angle between them should increase to 75°?

(30)

A The magnitude of the resultant would increase.

B The magnitude of the resultant would decrease.

C The magnitude of the resultant would not change.

YOUR ANSWER --- A

Refer to Figure 22 on page 24. The useful component is F_h since it is this part of the applied force which drags the sled along the snow horizontally.

Note in Figure 26 below what happens to the useful component when the angle between the ground and the rope is increased. The length of the F_h vector in Figure 26B is substantially shorter than in Figure 26A when the angle was 30°. Hence, increasing the angle does not increase the useful component of the applied force.

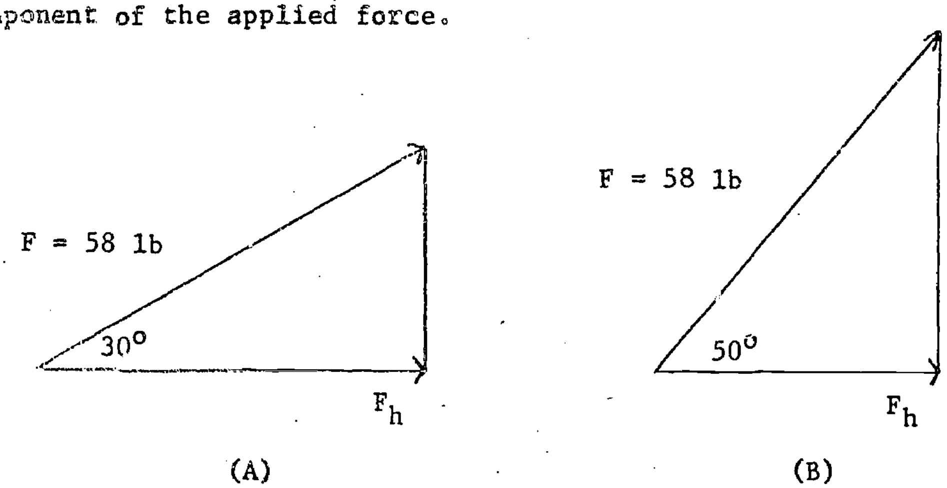


Figure 26

Please return to page 114 and select a better answer.

YOUR ANSWER --- B

You are correct. The only way a pair of forces can form either a 0° angle or a 180° angle is for them to lie on the same straight line, either in the same or in opposite directions. Such forces are <u>collinear</u> forces and represent the only conditions for which algebraic addition to find the net force is valid.

When you return to the original question, look carefully at Figure 5 on page 134 again. These forces are certainly not collinear; hence you cannot find their resultant by simple algebraic addition.

Please turn to page 89. This will take you to the page with the right answer to the original question.

YOUR ANSWER --- B

You are correct. The length of the resultant vector turns out to be very nearly 7.8 cm which, multiplied by 20, yields 156 lb. To 2 significant figures, this may be written as 160 lb.

At this point in our work, we want to define a new term that frequently appears in the study of forces. The word is equilibrant. (Pronounced ee kwil-i-brant). Refer to Figure 9.

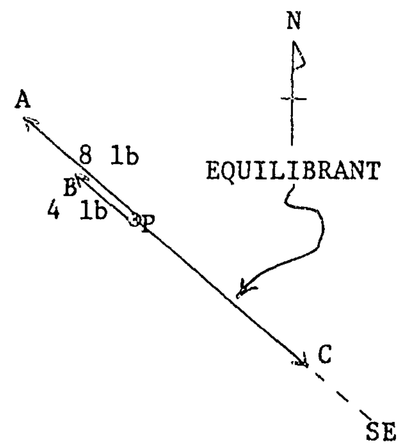


Figure 9

In this drawing, two forces (A and B) acting to the NW on point P tend to set this particle in motion. A and B are collinear, of course, and their resultant pull on P, or their net force on P is (+8 lb) + (+4 lb) = +12 lb. Suppose we wanted to keep particle P in equilibrium. We could then apply a force to it whose magnitude and direction were such as to balance the other forces exactly. This would result in a net force of zero and the motion of the particle would not change. The force needed to maintain equilibrium of a particle against the action of one or more other forces is called the equilibrant of the system.

So, in Figure 9, what is the magnitude and direction of the equilibrant?

Keep your answer in mind as you turn to page 13.

YOUR ANSWER --- B

No, your answer is not right.

The importance of strict adherence to a definition in physics cannot be overemphasized.

We defined a force as a push or a pull. This definition does not state, nor does it imply, that the push or pull must move something.

You have fallen into a kind of error that is sometimes called "associative." Your experience tells you that a force usually causes motion; therefore you conclude that unless motion is produced, a force cannot be acting. It is the kind of mistake that you have to be on the alert for. Stick to the definition even though your daily experiences seem to add ideas that are not really there.

Please return to page 4 and select the other answer.

YOUR ANSWER --- A

Think a moment. Is there no contact between your hand (the source of the force) and the sled? You might think there is not, but that is because you are limiting yourself to direct contact. Sure, your hand does not touch the sled, but indirect contact exists nevertheless since your hand pulls on the rope (by contact) and the rope pulls on the sled (by contact).

Thus, the idea of contact must include the possibility of transmitting the force through one or more other objects indirectly to the body upon which the force is ultimately to act.

Please return to page 18. Look over the other answers carefully before making another selection.

YOUR ANSWER --- A

This answer is not right. To see why it is wrong, we'll describe a simple experiment that you have performed many times without realizing it.

Imagine that you are on a very smoothly moving train going at, say, 60 mi/hr. The train's velocity is absolutely uniform. Resting on the table before you is a tiny cube of wood or metal. Now the cube is not a particle, but its dimensions are so small that we commit no grave error in considering it to be one.

Since the train is moving uniformly at 60 mi/hr with respect to the track, then the cube must also be moving at the same velocity. So, here we have a "particle" moving with absolutely uniform velocity. Next imagine that you apply two forces of equal magnitude with your fingers, pushing on opposite sides of the cube so that the forces are collinear and opposite in direction. You know very well that the cube will not move with respect to the table when you do this. Hence, if it was moving 60 mi/hr with respect to the track prior to application of the balanced forces, how fast is it now moving with respect to the track? Have you changed the <u>state of motion</u> of the particle at all?

With this picture in mind, you probably can answer the original question without difficulty.

Please return to page 55 and select the correct answer.

CORRECT ANSWER: Force A would be represented by a line segment 5 cm long on the basis of the scale: 1 cm = 10 lb.

Force B, of course, would also be represented by a line segment 5 cm long since this force is also 50 lb.

Step 2. As part of the data, you are told that the angle between the two forces is 60°. It is now necessary to lay out the vectors to scale with the given angle between them. The vectors must be connected head-to-tail. The easiest way to do this is illustrated in Figure 6. Place point P at a logical place. In this case, the net force is certainly going to extend from point P toward the right so point P should by placed well over to the left with some space above and below it as well. Draw the vector for A first, slanting it upward at approximately the same angle to the horizontal as it has in Figure 5. Extend the line beyond the necessary 5 cm as shown by means of a dotted line in the drawing. Measure and mark the point 5 cm from P.

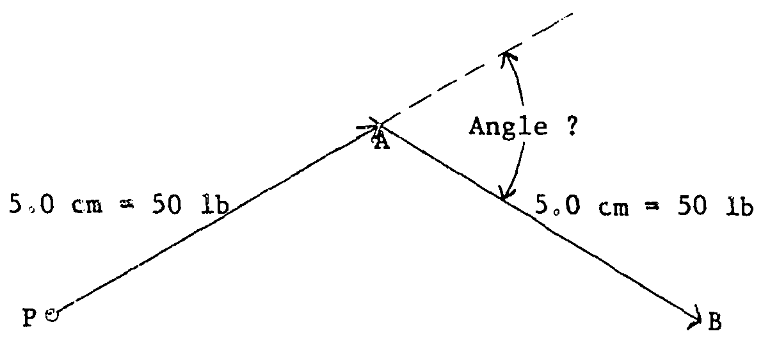


Figure 6

Now, draw in the line segment for force B starting at the 5 cm point and using a protractor to establish the correct direction. At what angle to the dotted extension of force A should the vector for force B be drawn?

Write your answer; turn to page 6 to check it.

CORRECT ANSWER: The angle between the taut ropes is 80°.

Now let's get to the problem. We want to know what net force is pulling the boat forward.

It will be convenient if we both use the same scale. Refer back to Figure 8 on page 15. Given below are 3 "possible" scales, only <u>one</u> of which is practical. Which one is it?

(15)

A Scale: 1 cm = 4 lb.

B Scale: 1 cm = 20 lb.

C Scale: 1 cm = 120 lb.

YOUR ANSWER --- A

This is incorrect on both counts.

Group 1 cannot be entirely correct because it has at least one error (possibly more!) as follows:

> A force of 0.4 lb east acting on the same point as a force of 1.5 lb west would have a resultant of 1.1 lb west. Since the equilibrant must have the same magnitude but opposite direction, then the equilibrant must be 1.1 lb east. The answer given, 1.1 lb west, has the wrong direction.

Group 2 cannot be all wrong because it has at least one correct answer (possibly more!) as follows:

> A force of 7.8 lb east acting on the same point as a force of 0.3 lb west would have a resultant of 7.5 lb east. Since the equilibrant must have the same magnitude but opposite direction, then the equilibrant must be 7.5 lb west. This is the answer given.

Please return to page 131. Remember, we want you to select one horizontal row in which both descriptions fit the facts.

YOUR ANSWER --- A

Not necessarily!

Assuming that the door opens inward into the room and is partially ajar, if you exert a 5-lb force inward, the door will open farther, won't it?

You gave that answer because you were not taking everything into account.

What else, besides the magnitude of the force needed to close the door, must you consider in answering this question?

Please return to page 10 and choose a more rigorous answer.

YOUR ANSWER --- A

Your vector resultant direction is correct but you have not measured your line segments and/or the angle between the forces with sufficient care. Your answer is smaller in magnitude than it should be. Perhaps this will help you to find where your drafting was inaccurate.

Please return to page 97. You should be able to choose the correct answer after locating your source of error in the answer you gave.

YOUR ANSWER --- D

You are absolutely correct. Excellent work! In every case you found the resultant and then accepted the force of equal magnitude and opposite direction as the equilibrant.

In Group 4:

(1.8 lb N) + (-0.6 lb S) = 1.2 lb N as resultant; thus equilibrant 1.2 lb S (correct answer given).
(15.4 lb E) + (+0.6 lb E) = 16.0 lb E as resultant; thus equilibrant 16.0 lb W (correct answer given).
(83.8 lb N) + (-92.0 lb S) = 8.2 lb S as resultant; thus equilibrant 8.2 lb N (correct answer given).

In Group 3:

(3.2 lb N) + (+4.0 lb N) = 7.2 lb N as resultant; equilibrant then 7.2 lb S (answer given is 7.2 lb N).
(8.7 lb W) + (+8.7 lb W) = 17.4 lb W as resultant; equilibrant then 17.4 lb E (answer given is 0.0 lb).
(0.4 lb W) + (-0.1 lb E) = 0.3 lb W as resultant; equilibrant then 0.3 lb E (answer given is 0.3 lb W).

Please go on to page 44.

We shall now apply our understanding of the equilibrant to forces that act at angles to each other. Suppose that two boys pull on a sled by means of ropes as shown in Figure 11. As you can see, the ropes each make an angle of 45° with the sled's axis. We want to determine the force that a third boy, pu[illegible]g straight back along the axis, would have to exert to prevent motic[illegible] the sled.

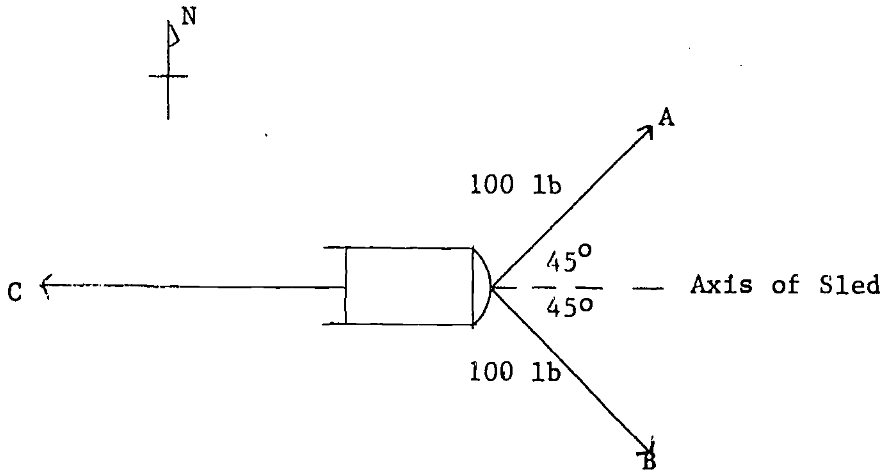


Figure 11

The two boys pulling forward are A and B; the boy who wants to prevent the sled from moving is C.

If force A and force B are considered the two original forces acting on particle P, then what name could we give the force exerted by boy C (force C)?

(19)

A The resultant of the two original forces.

B The equilibrant of the system.

YOUR ANSWER --- A

This is not quite right. When you say that the equilibrant is equal to the resultant, you are merely stating the magnitude of the force. But you know that a force is a vector quantity and cannot be fully described without stating its direction as well as its magnitude. To show you the weakness of this statement, we'll digress for the moment to Figure 10. The same two component forces, A and B, are shown in this drawing. Force C, also acting on P, is 12 lb. Thus, force C is equal to the resultant of A and B (8 lb + 4 lb = 12 lb). You can probably guess that particle P would move to the left under the influence of these three forces. Hence it is not in equilibrium.

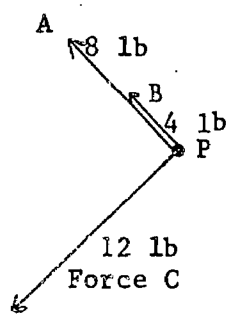


Figure 10

If force C in Figure 10 cannot produce equilibrium, then it is not an equilibrant. Hence, you cannot describe an equilibrant by merely saying that it is equal to the resultant.

Please return to page 13. Make use of the above ideas to help you select the correct answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

Why should it?

From your everyday experience, you know that in a perfectly matched tug-of-war between any forces, the particle on which the forces act does not tend to move.

Like the axioms in geometry, this is taken in physics as a self-evident truth.

You would be the most surprised person in the world if you were to see two precise 10-lb forces pulling in opposite directions on a particle, thus causing the particle to move toward either one of the forces, or in any other direction.

Please return to page 76 and select another answer.

YOUR ANSWER --- A

You are correct. Refer to Figure 13 on page 80. If balance A were shifted to the right until its string AP formed a straight line with string PW and if balance B were shifted to the left to accomplish the same line-up, then the sum of the readings of A and B would equal 5.5 lb.

For this condition, the balance forces would be collinear and exerted straight upward; then algebraic addition would be valid.

You can now select the right answer to the original question. Return to page 80.

YOUR ANSWER --- A

Incorrect. Always draw a rough diagram of the forces, not necessarily to an exact scale but at least approximately. See Figure 18.

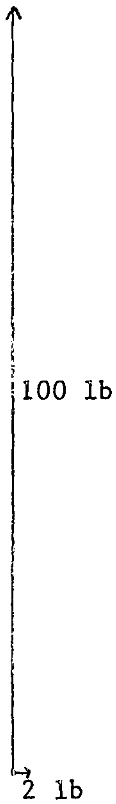


Figure 18

Just to get an idea of the relative sizes of the forces, we have drawn them roughly to scale. Then, if you visualize the kind of triangle that would be formed if you moved the 2-lb force up to join the head of the 100-lb force, you can easily compare the length of the hypotenuse with both of the other legs of the triangle.

Can you see now why the answer you selected is incorrect?

Please return to page 23 and select a better answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

This answer cannot be right because Figure 4B on page 113 is wrong. (This is not to say that the others are not wrong as well, but to prove your answer incorrect we shall show only one error in your thinking.)

In the case of B, the diagram indicates that the net force is 20 lb NW. Well, let's see. The two 20-lb forces are opposite collinear forces, hence have a resultant of zero; they cannot contribute to a resultant, then. The 40-lb force to the NW might be designated as (+), so the 10-lb force to the SE would have to be (-).

The resultant of these two forces is: (+40 lb) + (-10 lb) = +30 lb, or 30 lb to the NW. Since this does not correspond to the answer indicated on the diagram, B is wrong and so is your answer choice.

Please return to page 113. Select a better answer.

YOUR ANSWER --- A

You are correct. When we use the descriptions "useful" and "useless," we depend upon common sense to tell us which is which. In this example, and in similar ones, the horizontal component is the useful one and the vertical component is considered useless.

A picture of the forces is shown (not to scale) in Figure 23. The actual applied force is symbolized as F, while the direction of the horizontal component is F_h, and the useless or vertical component is F_v.

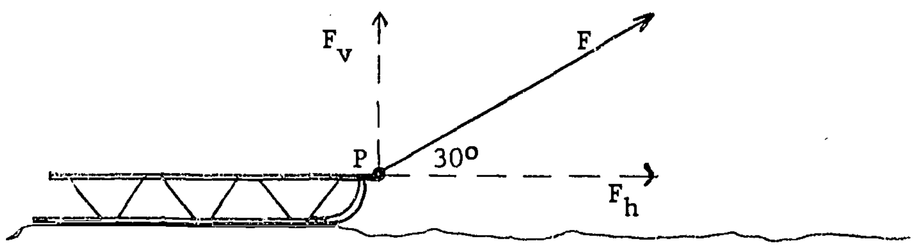
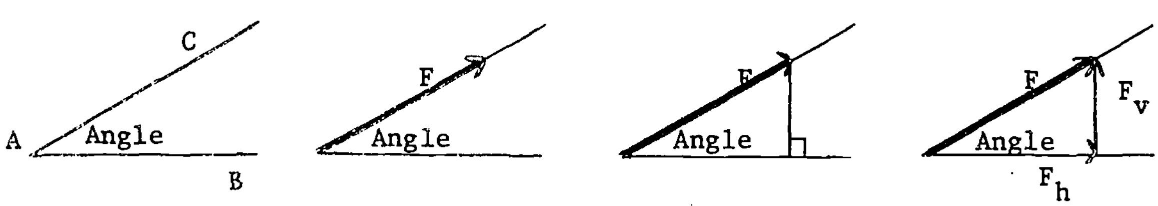


Figure 23

Our next objective is to determine the magnitudes of F_h and F_v. Do you remember how we performed the same operation on displacements and velocities? Refer to Figure 24 and mentally trace through the steps in finding the components of the force F.



Scale: 1 cm = ___

Step 1 Step 2 Step 3 Step 4

Figure 24

For a brief review of the vector resolution process turn to page 53.

If you feel that you recall the process of vector resolution reasonably well, turn to page 54.

Review of the Process of Vector Resolution: (Refer to Figure 24 on page 52)

Step 1: Draw a light straight line (AB) to represent the reference line to which the angle of the force is measured. In the sled example, this line is horizontal. Then lay out another light line at the specified angle at AB. This is AC in Step 1.

Step 2: Choose a sensible scale; you should finish with a vector picture that is large enough for clarity without running out of the assigned space. Measure F in terms of this scale, then darken the line segment along this length. Add the arrowhead.

Step 3: Drop a perpendicular from the arrow end of F to the reference line. Do this with either a compass or a protractor, but not by guesswork! This dropped perpendicular is indicated by the standard right-angle sign (∟). The new line may be drawn heavily.

Step 4: Place an arrowhead on the reference line where it intersects the perpendicular line; darken the line segment and label it (in this case) F_h. Place an arrowhead at the other end of the vertical line to establish the required head-to-tail connection; then label this line segment (in this case) F_v. Finally, determine the magnitudes of F_h and F_v from the scale.

Please return to page 52.

You arrived here because you feel sure you know vector resolution.

Getting back to the sled problem, assume that you are told that the boy pulls with a force of 58 lb (2 significant figures) on the rope, and that the rope makes an angle of 30^{o} with the ground. Determine the magnitude of the useful (horizontal) component of his force.

Draw the diagram to scale, measuring lengths and the angle with 2-significant-figure precision. Don't guess.

If you want to look at the review of vector resolution, you still can have the opportunity to run through it. Should you like to do so, turn to page 53.

If you still have your self-confidence, work the problem out and then select the answer below that is closest to yours. We have intentionally listed answers that are nearly alike in value, so you will have to work very precisely.

How large a force is the useful component?

(32)

A 48 lb.

B 50 lb.

C 52 lb.

YOUR ANSWER --- B

You are correct. If the particle is initially at rest, then the application of two collinear forces in opposite directions does not change this state of rest, provided that the forces are of equal magnitude.

We describe this condition as one of static equilibrium. "Static" means unmoving, and "equilibrium" means that the net force acting on the particle is zero. Since forces are vector quantities, they may be handled by the same set of rules we used in working with displacements and velocities. If a particle undergoes two displacements of equal magnitude in opposite directions, its net (or resultant) displacement is zero. Similarly for this case, the net force is zero, thus establishing the condition of static equilibrium for a particle initially at rest.

Now let us picture a particle moving with uniform velocity in space. Suppose we could, by some magnetic or electrical method, apply a pair of forces of equal magnitude and opposite direction to this uniformly moving particle. What do you think would happen to the particle's velocity?

(6)

A The speed of the particle would increase.

B The speed of the particle would decrease.

C The particle would then follow a curved path.

D The particle's velocity would remain unchanged.

CORRECT ANSWERS:

(a) The largest possible useful component is obtained when the angle between rope and ground is 0°. In this case, the entire applied force becomes useful.

(b) The useful component becomes zero when the angle is 90°. In this case, the entire applied force is wasted in pulling the front of the sled upward.

Now we'd like you to try a resolution problem.

A pupil wishes to open the upper half of a classroom window by pulling downward on a window pole hooked to the window fitting. This particular window requires a force of 75 lb applied by the fingers <u>straight downward</u> in order to get it started. If the pupil holds the window pole at an angle of 20° to the window, what force must he exert along the pole to open the window?

(Draw a suitable vector diagram. Then determine the required force by measurement to 2 significant figures.)

(35)

A 70 lb.

B 75 lb.

C 80 lb.

YOUR ANSWER --- B

You are correct. The diagram in Figure 18 points this out clearly. A vector picture, drawn to an approximate scale, permits you to arrive at descriptive (or qualitative) conclusions easily and quickly.

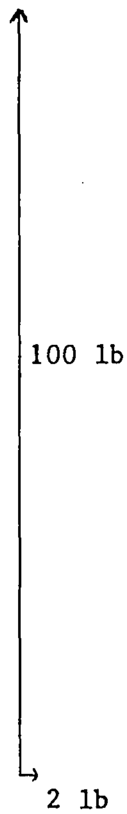


Figure 18

What must be true about two forces acting on the same particle if the resultant they produce is to make equal angles with each of the components?

(29)

A The two forces must have the same magnitudes.

B The angle between the forces must be 90°.

YOUR ANSWER --- B

The relationships of these forces is very important and must be thoroughly understood to solve this problem.

Refer to Figure 29 on page 115. Point P is, of course, in equilibrium because the problem says that the weight W is supported. The weight W acts downward; the boom acts on point P by pushing to the right. This means that the resultant of these two forces must act to the right and downward.

The tension, on the other hand, is a force that acts along the guy wire AP. With respect to point P, the only direction that the guy wire can be exerting a force is upward and to the left.

So, we leave it to you: can T be the resultant of W and B?

Please return to page 115 and choose the remaining answer.

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YOUR ANSWER --- C

You're being too cautious. Can you think of any circumstances at all where the direction of the force need not be stated in order to describe it fully? If you could think of even one such condition, we would agree that force may, therefore, be sometimes a scalar and sometimes a vector quamtity.

But we can't think of any such condition, and are fairly sure that you can't either. The very nature of a force demands that you tell the direction in which it acts; otherwise it is impossible to predict what it will do.

Please return to page 5 and select a better answer.

YOUR ANSWER --- C

You are correct. Very good thinking. Refer to Figure 13 on page 80. By taking force W as the equilibrant of A and B, you know at once that the resultant of A and B must have the same magnitude as force W but in the opposite direction. Thus, the resultant of A and B is a 5.5 lb force directed vertically upward. In general, then, any time you see a system of forces in equilibrium, the resultant of any two of them must be equal in magnitude to the remaining force, and in the opposite direction.

Before continuing, please turn to page 166 in the blue appendix.

Before going on the resolution of forces, that is, the process of breaking up a given force into rectangular components, we want to remind you that the Pythagorean theorem or special triangles may be used to find the resultant (and equilibrant) of a pair of forces acting at right angles to each other.

For example, suppose a force of 3 lb acts north on a given particle and a force of 4 lb acts west on the same particle. Draw the vector diagram for this and determine the magnitudes of the resultant and equilibrant.

Then turn to page 157 to check.

YOUR ANSWER --- B

You are correct. If the plane were perfectly horizontal, the weight of the object acting straight down along a vertical line would merely press the object against the surface. In this case there would be no sidewise force to disturb the vertical equilibrium of the object. The moment we tilt the plane, however, a sidewise force begins to act on the object, causing its state of motion to change.

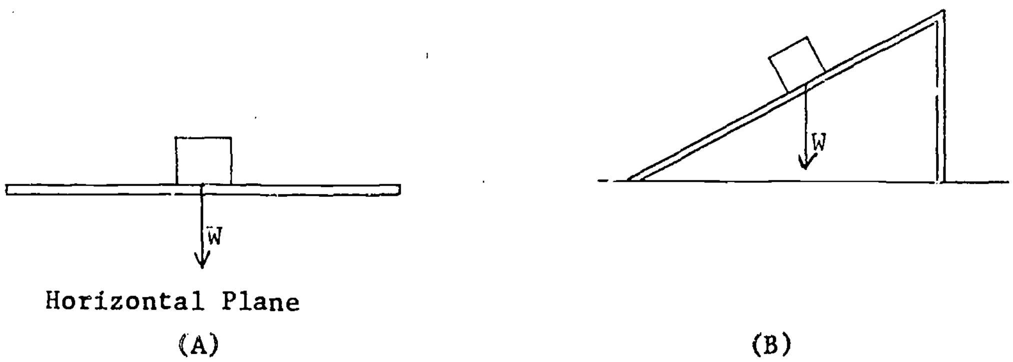

Figure 32

Refer to Figure 32. In A, the object is shown resting on a horizontal plane, its weight W acting vertically. In B, the right end of the plane has been raised but this does not affect the direction of force W on the body; W still acts vertically downward. For a frictionless plane, the object would now start to slide toward the lower end of the plane indicating that, as a result of tilting the plane, a force having a new direction has appeared; this is the only thing that will explain the motion of the object.

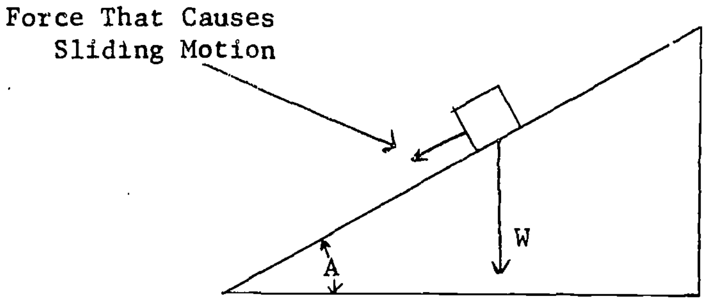

Figure 33

Does the tilting action change the magnitude of W?

(38) A Yes. B No.

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This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

You are correct. Refer to Figure 13 on page 80. If balance A were shifted to the right until its string AP formed a straight line with string PW and if balance B were shifted to the left to accomplish the same line-up, then the sum of the readings of A and B would equal 5.5 lb.

For this condition, the balance forces would be collinear and exerted straight upward; then algebraic addition would be valid.

You can now select the right answer to the original question. Return to page 80.

YOUR ANSWER --- A

Not necessarily, although this is sometimes true.

We are looking for a particular understanding here. What name have we been using for forces that act along the same straight line, either in the same direction or in opposite directions? Such forces, and only such forces, form angles of either 0° or 180° with each other.

Please return to page 25. Choose the other answer.

YOUR ANSWER --- A

If force A is taken as the equilibrant for B and W, then you could say that the resultant of B and W is a force of the same magnitude as the equilibrant you chose, force A, but opposite in direction.

But you don't want the resultant of B and W, do you? You're interested in finding the resultant of A and B, according to the question.

This signifies that you selected the wrong force to designate as the equilibrant of the system.

Please return to page 135 and select another answer.

YOUR ANSWER --- B

No, the speed would not decrease. To appreciate the reasoning here, we'll remind you of something you have probably done while riding on a train or in a car. Suppose the vehicle is moving with absolutely uniform velocity, smoothly and evenly. You have a tiny cube of wood or metal in your hand. Now, the cube is not a particle, but its dimensions are so small that we do not commit a serious error by considering it to be one.

If the vehicle is moving with an absolutely uniform velocity, say, 30 mi/hr, then the cube and the rest of the contents of the vehicle are also moving at 30 mi/hr with respect to the track or road. Next, imagine that you apply a squeezing force on the cube with your fingers, pressing on opposite faces of the cube with forces of equal magnitude and opposite direction. We are sure you will agree that the application of these balanced forces will not change the motion of the particle with respect to the track or road in any way whatsoever. It will still be riding along at 30 mi/hr with respect to the track or road.

Exactly the same thing applies to a particle moving with uniform velocity in space. Relative to any other body in space, the application of collinear balanced forces will not produce any change in the state of motion of the particle.

Please return to page 55. You can select the right answer now.

YOUR ANSWER --- A

You are correct. Refer to Figure 3 on page 78. By arbitrarily selecting force B as positive, you make the northeast direction (+) and the southwest direction (-). Since forces B and C are both headed toward the NE, both are (+); similarly, force A is headed SW and is (-).

What is the magnitude and direction of the net force or resultant force acting on P in Figure 3 on page 78?

(10)

A The net force on P is 7 lb to the NE.

B The net force on P is 4 lb to the NE.

C The net force on P is 1 lb to the SW.

YOUR ANSWER --- A

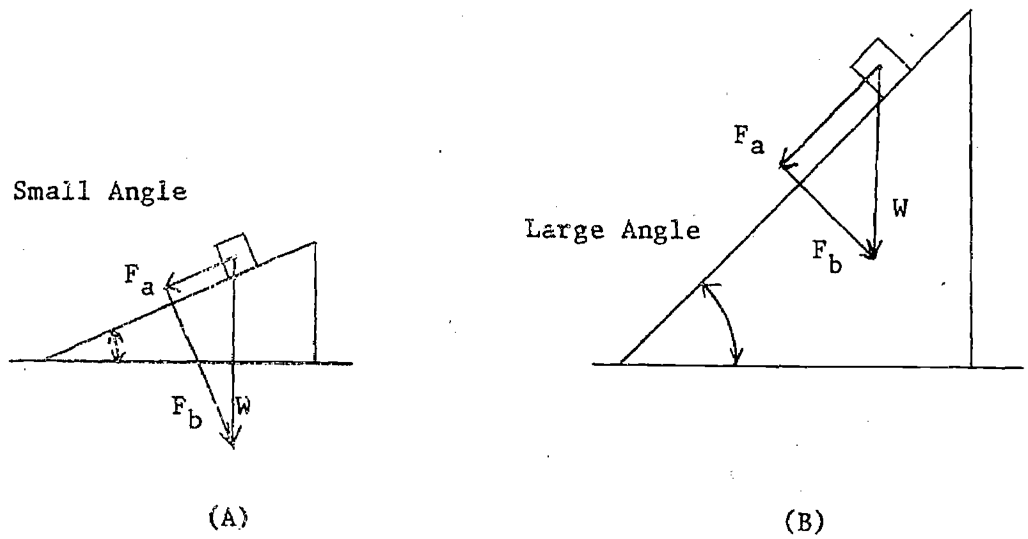


Figure 36

Figure 36 shows why your answer is incorrect.

As you study the two diagrams above, give all your attention to the way the original weight W is resolved in each drawing. See how the components F_a and F_b are joined head-to-tail in the approved manner; note that F_b is a perpendicular <u>dropped</u> from the arrow on the W force to the plane. The direction of F_a is parallel to the plane, its magnitude being determined by the point of intersection with F_b.

Now return to the original question and make another selection. Turn to page 110.

YOUR ANSWER --- B

To show why your answer selection is incorrect, we shall prove that one part of it is not acceptable. (This does not mean that the others are necessarily correct. They may or may not be.)

Refer to diagram C of Figure 4 on page 113. Your answer states that this diagram is wrong. This is not true. Altogether, there are 8 forces of 14.3 lb each acting on particle P. Actually, there are 4 pairs of balanced forces; that is, for any force you choose, there is one in the opposite direction of equal magnitude.

When all forces are balanced, the body is in equilibrium, either static or dynamic depending upon its initial state of motion. For a particle in equilibrium, the net force is zero. This is exactly the statement next to C, hence C is correct.

Please return to page 113 and choose a more appropriate answer.

YOUR ANSWER --- A

On the basis of this scale, the 120-lb force would be 30 cm long. A normal sheet of paper is not large enough to contain a vector diagram in which one of the components is represented by a 30-cm line segment. The diagram would be certain to overrun the edge.

We like large diagrams for the precision they make possible, but we don't want them to be so large that they are impractical. This one certainly would be.

Please return to page 39 and choose another scale.

YOUR ANSWER --- A

You are correct. The two 5-lb forces are collinear and oppositely directed; hence they have a resultant of zero; the same is true of the two 3-lb forces. Thus, the net force acting on the particle is zero and its velocity remains unchanged.

To introduce the next idea, we'll imagine that you are the luckless owner of a car that has gone into a roadside ditch with its rear wheels. You can't get behind it to push it out, but you do have a husky rope with you that can be secured to the front bumper. You decide to pull it out by means of the rope, but find that you cannot budge it despite your most valiant efforts.

Just then a passing car stops and four young men offer their help. All five of you then pull on the rope together. Slowly the wheels come out of the mud and the car is again on level ground.

For the sake of convenience, we'll assume that each of you was capable of pulling on the rope with a force of 130 lb.

1. What was the net force acting on the car?
2. What was the resultant of the individual forces?

Choose one answer:

(8)

A The net force was 650 lb and the resultant was zero.

B The net force was 650 lb and the resultant was 650 lb.

C The net force was 520 lb and the resultant was 520 lb.

YOUR ANSWER --- A

You are correct. We have seen convincing proof in a prior lesson that this method of vector addition yields correct results.

<u>Refer again to Figure 5 on page 134</u>. To find the net force acting on the sled, the following step-by-step method is recommended:

Step 1. Select a sensible scale that will give you a conveniently large vector diagram, yet one that will not run off the page. For this example, a good scale would be

1 cm = 10 lb.

On this basis, how long a line segment would you use to represent force A?

Write your answer; then turn to page 38 to check it.

YOUR ANSWER --- A

Refer to Figure 3 on page 78. You omitted one of the forces in your calculation. True enough, forces B and C, being collinear and in the same direction, add up algebraically this way: B + C = +2 lb + +5 lb = +7 lb.

But don't forget that there is a -3 lb force present, namely force A. This is certainly going to affect the magnitude of the net force, isn't it?

So, take force A into account.

Please return to page 69 and select the correct answer.

YOUR ANSWER --- B

You are correct. In this sense, gravitation is like magnetism. Any object near the earth's surface will fall to the ground (if it is unsupported) because a force is acting without contact.

Gravitation, unlike the pull on the rope that pulls the sled, can act on objects without the intervention of other material things. The same is true of electrical charges which you must have met in your earlier education. Charges can pull on each other or push on each other; a pair of similar magnetic poles repel each other while opposite magnetic poles attract each other. Gravitation, as we understand it today, can exert only an attracting force. If we ever discover how to produce anti-gravity, perhaps we shall have repulsion by gravitational forces.

NOTEBOOK ENTRY
Lesson 7

2. Forces may act by contact or over a distance.
   (a) Mechanical forces act by direct contact, or through the medium of intervening matter as in the case of a hand pulling a rope that pulls a sled.
   (b) Gravitational force, magnetic force, and electrical force are common examples of forces that act over a distance.

An important basic concept in mechanics is that of equilibrium.

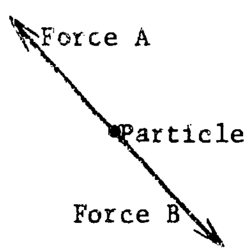


Figure 1

Refer to Figure 1. Two forces, A and B, of equal magnitude are acting on the same particle in exactly opposite directions. Will the body tend to move?

(5)

A Yes.

B No.

C Maybe.

YOUR ANSWER --- C

Of course, it is possible that an error was made in marking the hanging weight 5.5 lb. But this is hardly likely. Remember that we are viewing this as an actual laboratory experiment where such a gross error would have been corrected long before.

We'll have to assume that the weight is actually 5.5 lb as marked. Then what accounts for the disparity in the sum of the balance readings and the hanging weight? (You must also assume that the balances are accurate.)

The left-hand balance (balance A) is exerting its force along the line of the slanted string connecting its hook to the common knot that ties the strings together. Its stretched string produces a force that is mostly upward but not entirely; part of its pull is being wasted in a sidewise direction. The same is true of balance B on the right side. Thus, the force exerted by each balance is divided between upward and sidewise pulls.

Whenever forces act at angles this way, it will be found that the algebraic sum of the angled forces is greater than you might expect on first thoughts.

For only one set of circumstances would the sum of the balance readings equal the hanging weight. When would this happen?

(24)

A If the balances were arranged to exert their forces collinearly.

B If the forces exerted by the balances were equal to each other.

YOUR ANSWER --- B

You are correct. Collinear forces acting in the same direction may be added arithmetically to give the resultant or net force. Since net force and resultant have identical significance, whatever answer you write for one of them must also be written for the other.

Like other vector quantities, collinear forces may be assigned algebraic signs to distinguish between one direction and the opposite direction. The actual choice of sign for the first force you designate this way is purely arbitrary, but from that time on the signs are dictated by the relative direction.

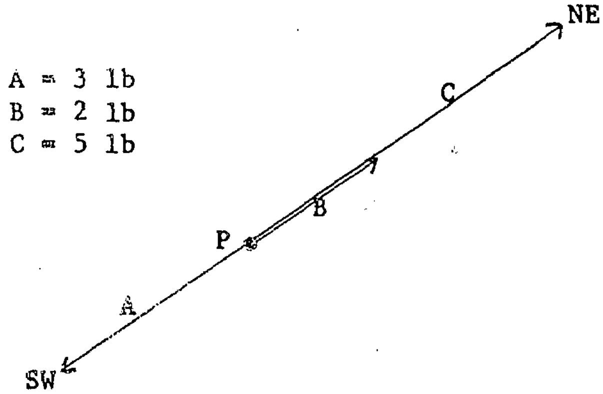


Figure 3

Refer to Figure 3. Three collinear forces are acting on a particle P. (Force B is to be thought of as lying on the same straight line as A and C; the diagram was drawn this way for clarity.) Suppose we agree to designate force B as the (+) force.

In that case, which one of the following is true?

(9)

A There are two (+) forces and one (-) force.

B There are two (-) forces and one (+) force.

YOUR ANSWER --- B

You are correct. The length of PC was measured at 7.1 cm and, from the scale 1 cm = 20 lb, the magnitude of the equilibrant force is therefore 140 lb to two significant figures.

NOTEBOOK ENTRY
Lesson 7

(Item 3)

(e) To find the equilibrant of two or more forces, first determine the direction and magnitude of the resultant of these forces; then take the equilibrant as equal in magnitude and opposite in direction.

(f) If the equilibrant of two or more forces is known, then the resultant of these two or more forces may be taken as equal in magnitude and opposite in direction to the known equilibrant.

Please go on to page 80.

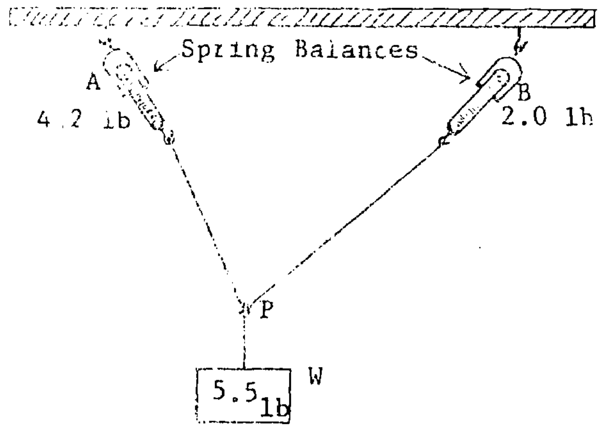


Figure 13

Refer to Figure 13. Two spring balances, secured to a plank, support a 5.5-lb weight by means of three strings as illustrated. Spring balance A reads 4.2 lb and B reads 2.0 lb. Consider this as an actual experiment performed in the laboratory with real balances, strings, and weight.

Anyone doing this experiment would notice immediately that the sum of the balance readings is not equal to the hanging weight. Which one of the following explanations would you choose as most probably correct?

(22)

A These are not collinear forces hence the resultant and equilibrant cannot be found by algebraic addition.

B The balances are probably inaccurate. If they were very accurate, then the sum of the balance readings would have to equal the hanging weight.

C The weight is incorrectly marked. Since the upward pull of the balances adds up to 6.2 lb, the hanging weight must really be 6.2 lb despite the marking on it.

YOUR ANSWER --- C

You selected an incorrect answer.

Refer to Figure 2 on page 112. As a start, what is the net force applied to the particle by the 5-lb forces? Since these are both 5 lb and oppositely directed, their resultant is zero, hence these forces are perfectly balanced and do not affect the particle in the least. Now consider the two 3-lb forces separately from the 5-lb forces. These are also perfectly balanced so that the net force they apply to the particle is zero.

So, you see, even though there are four separate forces acting on the particle, there is no net force at all and, as far as the particle is concerned, there are no forces present that can cause it to slow down, speed up, or change its direction of motion.

The particle is, therefore, in equilibrium.

Which kind of equilibrium do these conditions describe?

Please return to page 112 and choose a better answer.

YOUR ANSWER --- B

Up to a certain point, your thinking and your work were both excellent. But you stopped before you reached the end of the problem!

You found the resultant rather than the equilibrant. The magnitude is correct; the direction you give is correct for the resultant but not for the equilibrant.

Please return to page 158. Choose the right answer.

YOUR ANSWER --- C

That's not at all true.

If you were a Neanderthal man who had never thought of using wind as a motive force, you might wonder what caused a leaf to scoot across an otherwise still pond. The wind itself is invisible, but not being a Neanderthaler, you know what it is. Wind, of course, is air in motion, and air consists of molecules of various kinds. Each of these molecules has mass and can push against the sail of the boat. And, since they come in contact with either the sail or each other, the force is transmitted to the sail by contact. A wind blowing on the trees on shore cannot move the sailboat in a sheltered cove. We must wait until the air molecules complete their trip to the sail before we can expect them to be capable of exerting a force on it.

Please return to page 18 and select another answer.

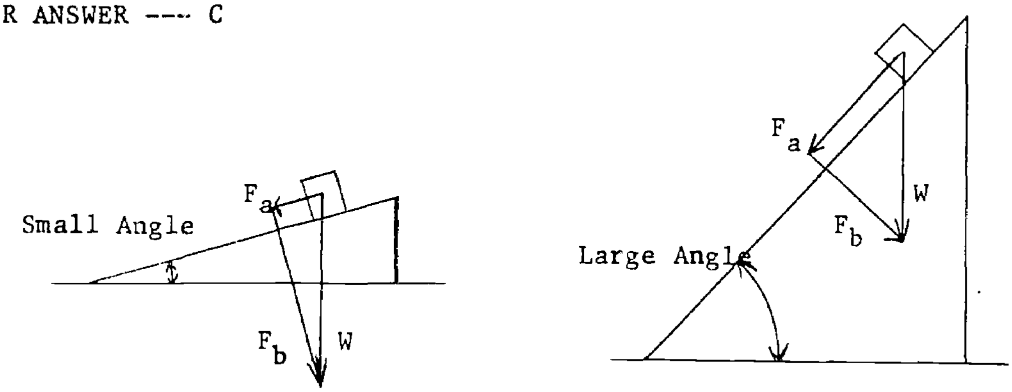
YOUR ANSWER --- B

That is not true. If the two balances were arranged so that their string lengths were identical, the weight would then hang symmetrically between them and both balances would read the same, yet the sum of their readings would still be greater than the hanging weight.

Whether or not the balance readings are equal, they will total to a greater figure than the hanging weight as long as the balance strings make an angle with each other greater than zero.

Please return to page 77 and choose the alternative answer.

YOUR ANSWER ---- C



(A) (B)

Figure 36

Figure 36 shows why your answer is incorrect.

Study the two diagrams. Give all your attention to the way the original weight W is resolved in each drawing. See how the components F_a and F_b are joined head-to-tail in the approved manner; note that F_b is a perpendicular dropped from the arrow end of W to the plane. The direction of F_a is parallel to the plane, its magnitude being determined by the distance you have to extend it so that it intersects F_b.

Now return to the original question and make another selection. Turn to page 110.

YOUR ANSWER --- B

Not good enough. You can do better with more care in measurement (particularly the 23° angle). If necessary, redraw the diagram.

Please return to page 121. Choose another answer on the basis of your new diagram.

YOUR ANSWER --- C

Not quite right. When you say that the equilibrant is equal to the sum of the component forces, you are merely stating the magnitude of the force. But you know that a force is a vector quantity and cannot be <u>fully</u> described without stating its direction as well as its magnitude. To show you the inadequacy of this answer, let's refer to Figure 10. In Figure 10, A and B are again the component forces, while C is a 12-lb force that is equal to the sum of the components since 4 + 8 = 12. But can C produce equilibrium of particle P against the action of A and B? Of course it cannot. There is no difficulty in seeing that particle P would move to the left if A, B, and C were all acting on it at the same time.

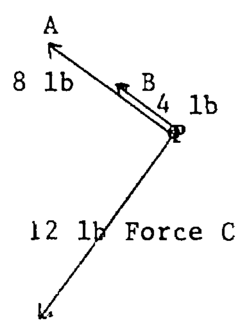


Figure 10

Thus, force C does not maintain equilibrium of P at all. Therefore it cannot be the equilibrant of the system. You cannot describe an equilibrant merely by saying that it is equal to the sum of the component forces.

Please return to page 13. Make use of the above ideas to help you select the correct answer.

YOUR ANSWER --- C

What could possibly cause it to move?

Your daily experiences tell you that when two forces of equal magnitude act in exactly opposite directions on the same particle, the particle does not tend to move in any direction whatever.

The only way we can account for the "maybe" in your answer is to think that you assumed the forces weren't exactly opposite, or that the particle was stretched. But a particle is dimensionless, like a geometric point located where the forces meet.

Imagine two spring scales pulling in opposite directions on a piece of string. As long as the scales don't move, will the piece of string move?

Please return to page 76 and select the right answer.

YOUR ANSWER --- B

You are correct. Only collinear forces may be added algebraically to determine the net force.

In an earlier lesson, you learned how to determine the resultant of two displacements that took place at any angle. The same procedure was used for adding velocities at angles to each other. This technique may be applied to any type of vector including force vectors.

Briefly, two vectors that are not collinear may be added by scaling the quantities, drawing line segments to scale with arrowheads, connecting them to each other, and forming a triangle by drawing in the remaining side. If the line segments are properly joined, the remaining side of the vector triangle is the resultant or net vector, showing the correct direction and magnitude according to the arbitrary scale.

What is the proper technique for joining vectors in the addition process?

(14)

A Head to tail.

B Head to head.

C Tail to tail.

YOUR ANSWER --- B

No, this is not correct. An angle of 90° is not a requirement. Figure 19 should help you.

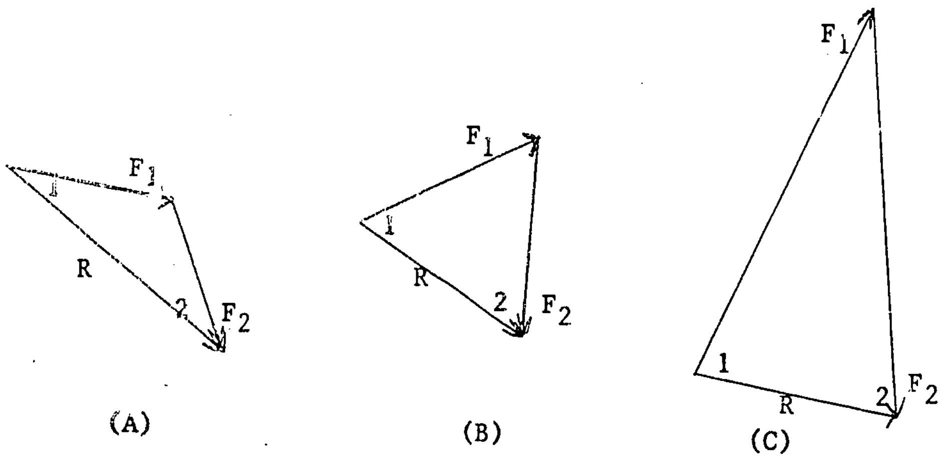


Figure 19

The three drawings are vector diagrams, each showing two forces, F_1 and F_2, acting on a particle. You will note that the angles between the resultant and each of the two forces (angles 1 and 2) are the same in all three cases, yet there is not a single diagram where the components act at right angles to each other.

You can see from the diagrams what is the true requirement for equal angles.

So return to page 57 now, and pick the remaining answer.

YOUR ANSWER --- C

Review your notes on vector addition. This is not correct.

Please return to page 89 after reviewing your notes. You will then be able to select the right answer.

YOUR ANSWER --- B

Refer to Figure 3 on page 78. Force B has been arbitrarily chosen as the (+) force. This means that the northeast (NE) direction is positive and the SW direction is negative.

So, if NE is positive, then force C must be labeled (+) as well as force B. And in that case, force A must be (-). Now count the (+) and (-) forces. How many of each are there?

Please return to page 78. Choose the correct answer.

YOUR ANSWER --- B

You are correct. That wasn't too hard, was it? You will discover that none of the problems in resolution are especially difficult as long as you follow the logical steps we have taught you. Let's jot down some important points regarding resolution of forces.

NOTEBOOK ENTRY
Lesson 7

4. Resolution of Forces

(a) Any force may be resolved into an infinite number of different components.
(b) To resolve a force, sufficient information must be given so that you can determine the required directions of the components.
(c) The rectangular components of a given force are those components that act at right angles to each other. There is only one pair of horizontal and vertical components for any given force.
(d) The useful component is that part of the applied force which enables the agency that applies the force to accomplish its objective. The useless component is that part of the force that is wasted.

Examples: When a sled is pulled horizontally by a rope that makes an angle to the ground, the useful component is the horizontal one.

When a window pole is used to push a window up and is held at an angle to the wall, the useful component is the vertical one, in this case.

(e) A force may be resolved into its rectangular components by means of either (1) a scale diagram or (2) methods of trigonometry.

Please go on to page 94.

Notebook Check

While we're looking at the notebock, let's review a little. Referring to the notes under item 3 in this lesson, what is given in item 3(d)?

(33)

A It defines the condition of dynamic equilibrium.

B It defines and describes an equilibrant.

C It states the relationship between a resultant and an equilibrant.

D It describes the method of determining the equilibrant.

YOUR ANSWER --- B

You are correct. If this question sounded a bit on the silly side, please bear with us. We just want to make certain that there are no misunderstandings even with respect to these very basic ideas.

So there is no sidewise force acting on an object resting on a horizontal plane; when the plane is tilted, a sidewise force suddenly appears, apparently out of nowhere.

Well, where does this sidewise force have its origin? Clearly, this force must be produced by gravitation. By tilting the plane, we change the direction of W with respect to the plane (but not with respect to the Earth, of course). So now W may be thought of as having two distinct parts: (1) the part that continues to press the object against the plane surface, and (2) the part that causes the object to slide down the plane.

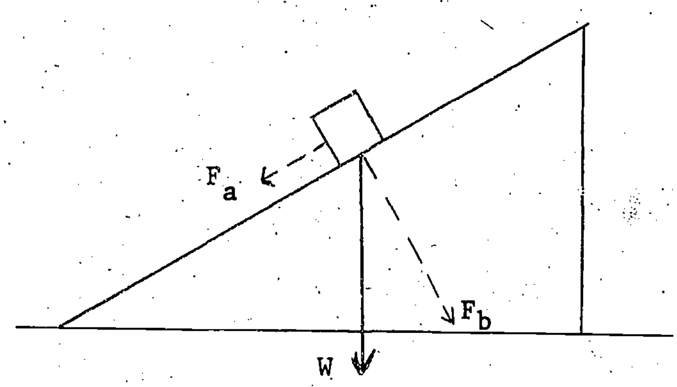


Figure 34

Refer to Figure 34. The "sliding" force is F_a in the diagram; the "perpendicular" force is F_b. Now, since both of these forces have their origin in the weight W of the object, no new forces having been brought to bear, common sense tells us that the vector sum of F_a and F_b must turn out to be equal to W. Therefore, if we take F_a and F_b as component forces, how is W related to them?

(39)

A W may be considered as the "resultant" of F_a and F_b.

B W may be considered as the "equilibrant" of F_a and F_b.

YOUR ANSWER --- D

Not good enough.

Repeat your measurements, especially the 23^{o} angle. You need to be more precise.

Please return to page 121. Choose another answer on the basis of your revised measurements.

YOUR ANSWER ---- B

You are correct. An equilibrant is a single force that maintains the equilibrium of a particle despite the presence of other forces acting on the same particle.

Then our problem calls for the determination of the magnitude of the equilibrant of the system of forces shown in Figure 11 on page 44.

We have not developed a way of finding the equilibrant of a system of forces <u>directly</u>, but we do know how to find the resultant of the original forces. And, of course, once we know the resultant <u>we also know the equilibrant</u> because the latter is equal in magnitude and opposite in direction to the former. So let's find the resultant of A and B in Figure 11 on page 44 employing the familiar graphical method. Use as your scale 1 cm = 20 lb.

Work carefully; then choose one of the answers below: (Note: assume data correct to 2 significant figures.)

(20)

A [illegible]sultant of A and B is 130 lb to the east.

B Th[illegible]esultant of A and B is 140 lb to the east.

C The resultant of A and B is 140 lb to the west.

D The resultant of A and B is 150 lb to the west.

YOUR ANSWER --- B

This answer would be right if the boy wanted to dump his rider off the back of the sled into the snow!

But we don't think this is his aim, as you will agree. He's pulling the sled for the express prupose of moving it horizontally along the snow. Hence, the useful component cannot be the part of his force pulling upward. In a normal sled-pulling situation, the vertical component is designated as the useless component while the horizontal one is taken as the useful component.

Please return to page 24. The other answer is, as you now know, the correct one.

YOUR ANSWER --- A

This answer is not acceptable. We used a scale of 1 cm = 10 lb as you can see in Figure 25. In measuring the length of the force vector to 2 significant figures, it is not at all difficult to avoid even a small error. However, the angle measurement must be very carefully done; otherwise your answer may go off by quite a percentage. Perhaps your carelessness lay in your measurement of the angle. Check this as well as the vector length measurement.

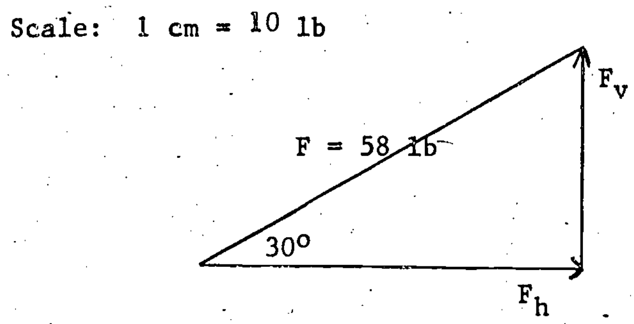


Figure 25

Please return to page 54 and check your measurements. We are sure you can obtain a closer answer.

YOUR ANSWER --- A

There is some ccnfusion in your mind with respect to the connection between net force and resultant.

The phrase "net force" means exactly the same thing as resultant. If the net force in any situation turns out to be x lb, then the resultant is also x lb.

In the action described, there are 5 collinear forces all acting in the same direction, each of 130 lb. Whatever answer you get for the net force is also the value of the resultant.

Please return to page 73 and choose the right answer.

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YOUR ANSWER --- A

This is incorrect.

Dynamic equilibrium is defined in topic 3(b), which reads as follows:

> (b) If a body is initially in motion with uniform velocity, the application of balanced forces will produce no change in its motion. It will not slow down, speed up, alter its direction, or stop. This condition is known as <u>dynamic equilibrium</u>.

Please return to page 94 and choose another answer.

YOUR ANSWER --- C

No, it would not. Your thinking may be clarified by considering a simple act that you have probably performed many times. Imagine that you are in a train that is traveling with perfectly uniform speed on a perfectly smooth, straight track. In your hand is a tiny cube of wood or metal. If the train is traveling uniformly at 60 mi/hr, then every object in the train is traveling at the same speed with respect to the ground outside.

Next, imagine that you place the cube between your fingers and squeeze it, directing the forces opposite to each other in direction and with equal magnitude. We are sure that you will agree that these balanced forces will not cause the cube to move one way or the other in the train. In other words, these balanced forces have not changed the state of motion of the cube with respect to the ground; it is still moving with a uniform velocity in a straight path. It will certainly not go into a curved path while the train continues in a straight line.

Note that we often use a small real body, such as a cube, instead of a particle. A theoretical particle is dimensionless like a geometric point; but a tiny bit of matter may be considered to be a particle for practical purposes.

Please return to page 55. You now have enough clues to enable you to select the right answer.

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YOUR ANSWER --- B

Correct! Your scale, then, will be 1 cm = 20 lb.

Before you start to find the net force pulling the boat forward, we suggest that you read over the few hints given below.

Refer to Figure 8 on page 15. Draw light free-hand lines to represent the river banks. Position point P near the north bank as in Figure 8. Draw the keel-line very lightly and measure a 30° angle upward for the direction of boy A's force. Draw a line segment for the 120-lb force of the proper length (to scale) and then extend it beyond this point as a dotted line. Carry on from there on your own.

Make your measurements, both lengths and angles, very carefully. Do whatever is required to determine the net force acting on the boat in a forward direction. Then compare your answers with those below, selecting the one that is closest in magnitude to yours. (Small errors are anticipated due to the nature of the problem.)

(16)

A Net forward force = 136 lb (or 140 lb to 2 significant figures).

B Net forward force = 156 lb (or 160 lb to 2 significant figures).

C Net forward force = 173 lb (or 170 lb to 2 significant figures).

CORRECT ANSWER: In Figure 35 on page 149, the larger of the two component forces is the perpendicular force, MN.

OM is the sliding force (F_a) and MN is the perpendicular force (F_b).

If you can, picture in your mind a sequence of positions of the plane where the angle is slowly being increased. If such a mental picture is difficult for you, make a series of perhaps four drawings, starting with a small angle and gradually increasing this angle. In each diagram show how W is resolved into the two components F_a and F_b.

With respect to this gradually increasing angle, select the only true statement from those below.

If the angle of inclination of a plane is gradually increased, what happens to the components of force?

(40)

A Both the sliding and perpendicular forces increase.

B The sliding force increases, but the perpendicular force decreases.

C Both the sliding and perpendicular forces decrease.

D The perpendicular force increases but the sliding force decreases.

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YOUR ANSWER --- D

You are correct. The forces would "balance themselves" leaving a net force of zero. With zero force acting on the particle, there would be nothing acting on it to make it increase or decrease its speed, nor change the straightness of its path.

Such a moving particle is said to be in dynamic equilibrium. "Dynamic" means moving; "equilibrium" means that the net force acting on the particle is zero.

NOTEBOOK ENTRY
Lesson 7

3. Equilibrium conditions.
   (a) If a body is initially at rest and balanced forces are applied to it, it will remain at rest. This condition is known as static equilibrium.
   (b) If a body is initially in motion with uniform velocity, the application of balanced forces will produce no change in its motion. It will not slow down, speed up, alter its direction, or stop. This condition is known as dynamic equilibrium.

Before continuing, please turn to page 165 in the blue appendix.

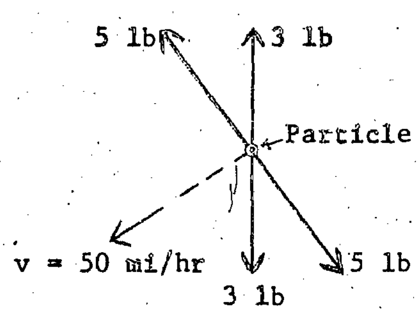

Figure 2

Now refer to Figure 2. The particle illustrated is moving with uniform velocity in the direction shown by the dashed arrow. Acting on it are four forces as shown. Which one of the statements below correctly describes the situation?

(7)

A The particle is in dynamic equilibrium.

B The particle is in static equilibrium.

C The particle is not in equilibrium.

YOUR ANSWER --- B

You are correct. Refer to Figure 3 on page 78. The algebra goes like this:

$$\text{Net force} = A + B + C$$
$$= (-3 \text{ lb}) + (+2 \text{ lb}) + (+5 \text{ lb})$$
$$= +4 \text{ lb}.$$

Since the (+) direction is NE, then the answer is 4 lb to the NE.

For practice, run through the diagrams in Figure 4, with a view to answering the question below.

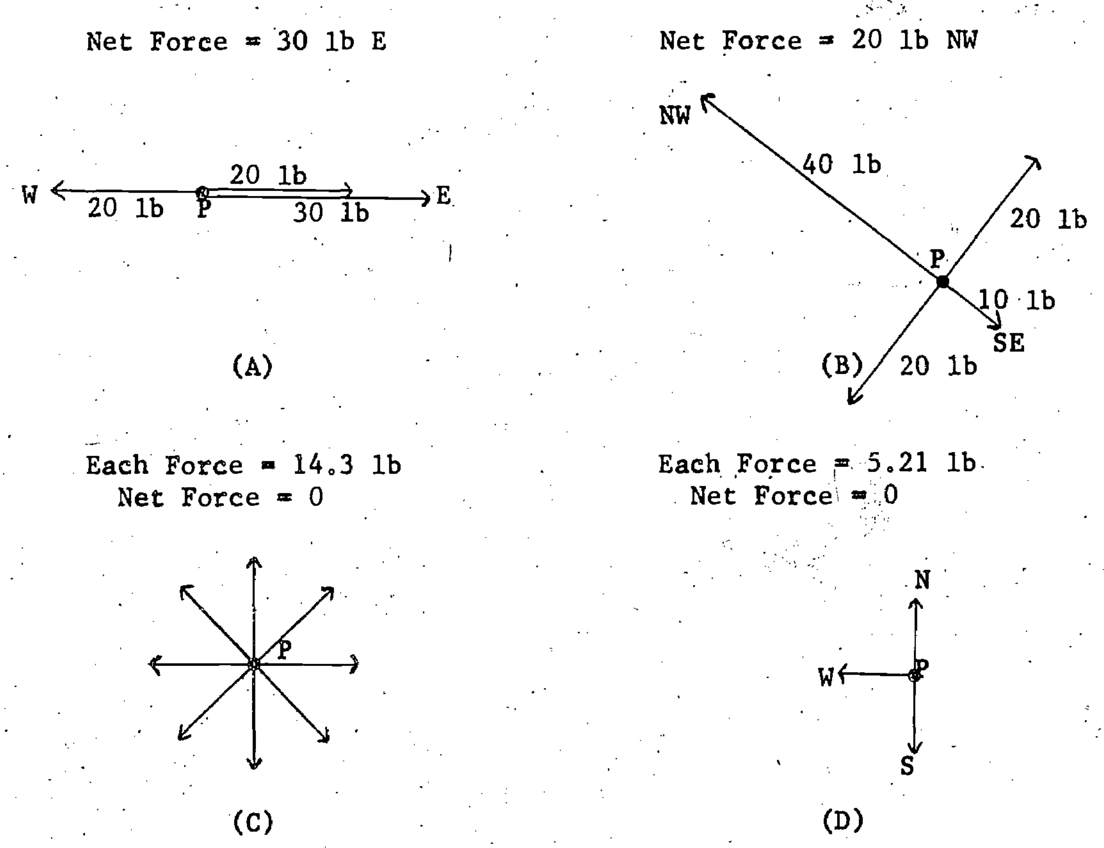

Figure 4

There is only one true statement in the following group. Choose it.

(11)

A A, B, and C are correct.

B B, C, and D are wrong.

C A and C are right.

D A and D are wrong.

YOUR ANSWER --- B

This is correct.

Returning to the sled example, as illustrated in Figure 22 on page 24, by which of the following methods could the boy increase the useful component of his force <u>without pulling harder</u> on the rope?

(34)

A By raising the rope so that the angle is greater than 30^{o}.

B By lowering the rope so that the angle is less than 30^{o}.

C By shortening the rope without changing the angle so that his force is exerted closer to the sled.

YOUR ANSWER --- C

You are correct. Figure 28 describes the problem in vector form. The line segment representing F is very closely 8.0 cm in length, so F = 80 lb.

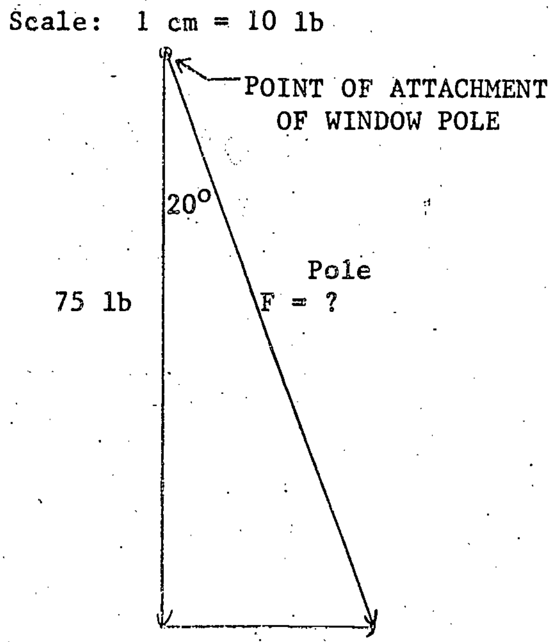

Figure 28

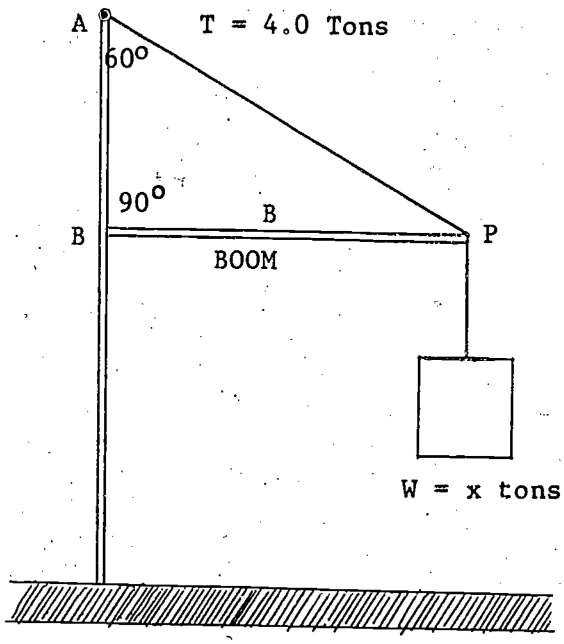

Figure 29

Now for a slightly different type of problem, refer to Figure 29. An upright pole supports a weight of x tons by means of a perfectly horizontal boom and accompanying cable. The guy wire makes an angle of 60° with the pole and is under a tension, T, of 4.0 tons.

Our problem is to determine the weight W. We'll handle this problem in a few steps.

First, draw the vector diagram correctly. To do this, you must first interpret the forces properly. There are 3 forces: (1) the weight W; (2) the tension T and (3) the push of the boom B on point P.

If we consider the two original forces as W and B, then what is T?

(36)

A <u>T</u> is the equilibrant for W and B.

B <u>T</u> is the resultant of W and B.

YOUR ANSWER --- A

You may have misunderstood the question. Picture a perfectly greased plank on which rests a greased wooden cube. If the plank is perfectly horizontal, and if only gravitational force acts on the cube, the latter would tend to remain in position. Since gravitational force acts vertically, an object on a true horizontal plane would merely be pulled downward against the surface. There would be no forces acting sidewise on it to make it move along the plane, one way or the other.

Now if one end of the plane is lifted to form an incline, the object will begin to slide toward the lower end gathering speed as it goes. This means that some sidewise force must now exist; otherwise the object would have remained in equilibrium.

Please return to page 146 and select the other answer.

YOUR ANSWER --- A

This is not true.

Weight is determined by the nature of the object and the planet exerting the gravitational pull on the object, as well as the distance between the centers of the two. (We shall be studying gravitation in detail later.)

But weight is not affected by the kind of surface an object rests on, nor its inclination to the horizontal.

For all problems, you may safely assume that the weight of any object is constant for a given location on Earth.

Please return to page 62 and choose the remaining answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- C

Apparently your vector draftsmanship is quite good, but you have erred in direction. Check over your arrowheads on the vector line segments. The resultant is definitely not directed toward the west.

Please return to page 97. Then select a better answer.

YOUR ANSWER --- C

This answer shows that you are fully aware that net force and resultant represent identical quantities in this example. That's fine.

However, you did not take into account all 5 of the forces. Each of these is 130 lb in magnitude; hence the total force magnitude is the sum of five 130-lb forces. Apparently, you added up only four of them.

Please return to page 73. Pick another answer.

YOUR ANSWER --- B

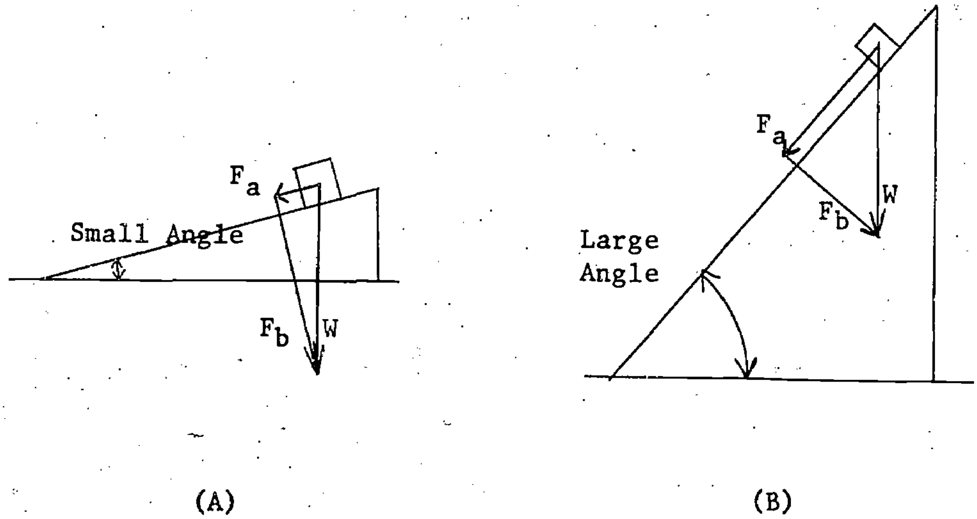

Figure 36

You are correct. The drawings in Figure 36 show why the sliding force (F_a) parallel to the plane increases while the perpendicular force (F_b) decreases as the angle is increased.

We'll conclude the new-material portion of this lesson with a numerical problem based upon resolution of forces on an inclined plane.

A block weighing 20 lb rests on a frictionless inclined plane which makes an angle of 23° to the horizontal table on which it is placed. How much force would you have to exert upward along the plane (parallel to it) to maintain the block in equilibrium? (2 significant figures.)

(41)

A 7.0 lb.

B 7.5 lb.

C 8.0 lb.

D 8.5 lb.

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YOUR ANSWER --- D

This answer is incorrect on two counts. The magnitude is wrong, probably as a result of inaccurate draftsmanship. The direction is wrong, too. You should give more attention to vector directions.

Review what you have done to ascertain where the error might lie.

Then return to page 97 and choose another answer.

YOUR ANSWER --- D

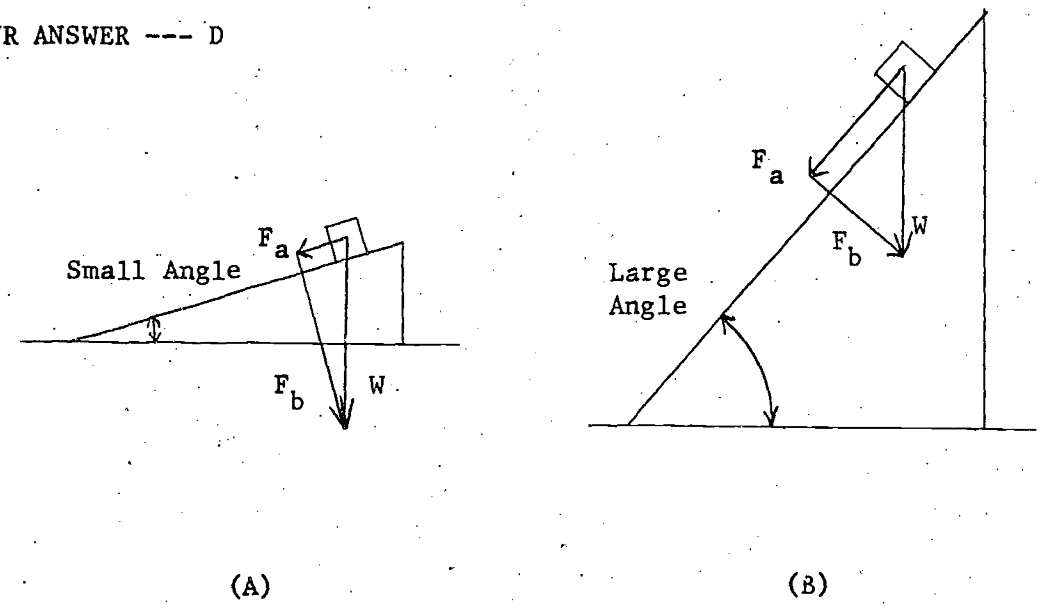

Figure 36

Figure 36 shows why your answer is incorrect.

Study the two diagrams. Give all your attention to the way the original weight W is resolved in each drawing. See how the components F_a and F_b are joined head-to-tail in the approved manner; note that F_b was constructed by dropping a perpendicular from the arrow end of W to the plane. The direction of F_a is parallel to the plane, its magnitude being determined by the distance that F_a must be extended to make it intersect F_b.

Now return to the original question. Turn to page 110 and choose a better answer.

YOUR ANSWER --- B

You are absolutely correct. Good! A force such as the equilibrant may be fully described only by stating its proper magnitude and direction. Clearly, in Figure 9 on page 34, force C is an equilibrant because it will maintain the equilibrium of particle P despite the fact that a resultant force of 12 lb due to A and B is acting in the opposite direction.

NOTEBOOK ENTRY
Lesson 7

(Item 3)

(c) The resultant of two or more forces acting on a given particle may be described as a single force that could replace the original (component) forces and produce the same effect.

Example: Two forces of 3 lb acting on a particle in a northerly direction could be replaced by a single 6-lb force acting on the same particle in the same direction to produce an identical effect.

(d) The equilibrant in a system of forces is a single force which, when applied to the same particle as the other forces, can maintain the particle in equilibrium.

(1) If a given force system consists of forces A and B acting on a particle, then the equilibrant of this system has a magnitude equal to the resultant of A and B, but has a direction opposite this resultant.

Example: If forces A and B are 3 lb and 8 lb respectively, both directed north, then the resultant is an 11-lb force north. The equilibrant, therefore, is an 11-lb force acting south on the same particle.

Please go on to page 130.

We have shown that the equilibrant for one or more collinear forces acting on a particle is a single force which is equal in magnitude to the resultant of these original forces, and opposite in direction. In a little while, we'll see that the component forces need not be collinear to use this definition of an equilibrant; that the equilibrant is always equal to the magnitude of the resultant of any number of forces acting on a particle at any angle, and is always opposite in direction to the resultant.

We feel, however, that you ought to practice a bit with determining the equilibrant of collinear forces before we venture into forces acting at other angles to each other.

Each of the groups below states the magnitudes and directions of a pair of forces. Only one of these groups contains no errors at all. Work out the equilibrant for each case and locate the error-free group. Also, one group is entirely incorrect. Locate it.

Group 1

Force A	Force B	Equil.
5.0 lb W	3.0 lb W	8.0 lb E
7.3 lb N	2.7 lb N	10.0 lb S
0.4 lb E	1.5 lb W	1.1 lb W

Group 2

Force A	Force B	Equil.
7.8 lb E	0.3 lb W	7.5 lb W
6.0 lb W	1.1 lb E	4.9 lb E
1.9 lb N	7.1 lb N	9.0 lb N

Group 3

Force A	Force B	Equil.
3.2 lb N	4.0 lb N	7.2 lb N
8.7 lb W	8.7 lb W	0.0 lb
0.4 lb W	0.1 lb E	0.3 lb W

Group 4

Force A	Force B	Equil.
1.8 lb N	0.6 lb S	1.2 lb S
15.4 lb E	0.6 lb E	16.0 lb W
83.8 lb N	92.0 lb S	8.2 lb N

Be sure you work out each one on paper. You must know which group is entirely correct and which group has all wrong answers. Then turn to page 131.

We assume that you have worked out all of the items in each group and therefore have written information in front of you that will enable you to give the number of the group that contains all correct answers and the number of the group that contains all incorrect answers.

If they are not fully worked out, return to page 130 and copy every example on scrap paper. Work out each one in writing; then return to this page.

If you did work them out fully, you can now select the correct answer from those below: (Both descriptions must fit the facts.)

(18)

	Entirely Correct	All Wrong
A	Group 1	Group 2
B	Group 2	Group 1
C	Group 3	Group 4
D	Group 4	Group 3

YOUR ANSWER --- B

That is not true. If the two balances were arranged so that their string lengths were identical, the weight would then hang symmetrically between them and both balances would read the same, yet the sum of their readings would still be greater than the hanging weight.

Whether or not the balance readings are equal, they will total to a greater figure than the hanging weight as long as the balance strings make an angle with each other <u>greater than zero</u>.

Please return to page 27 and choose the alternative answer.

YOUR ANSWER --- D

This choice was incorrect. Whether you use a special triangle or the Pythagorean theorem, a right triangle having one arm of 5 units and the other of 12 units cannot have a hypotenuse of 14 units.

In addition, the equilibrant cannot, under any circumstances, have a direction east of north.

The correct vector picture is started for you in Figure 16.

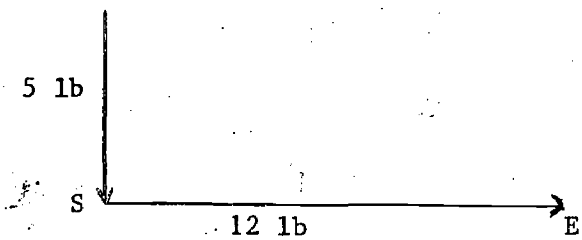

Figure 16

Please return to page 158. Reread the problem and do it again, if necessary, until you obtain one of the other answers given.

YOUR ANSWER --- C

You are correct. Referring to Figure 4 on page 113, go through the following solutions:

A. East is (+).
Net F = (+20) + (+30) + (-20)
= +30 lb = 30 lb E. (RIGHT)

B. NW is (+). The 20-lb forces cancel and do not contribute.
Net F = (+40) + (-10)
= +30 lb = 30 lb NW. (WRONG)

C. Four pairs of balanced forces.
Net F = 0. (RIGHT)

D. N and S forces balanced, leaving only W force of 5.21 lb.
Net F = 5.21 lb W. (WRONG)

We are about ready to start working with forces that act on the same particle but are not collinear.

Two boys pull on a sled with the aid of ropes in the manner shown (Figure 5):

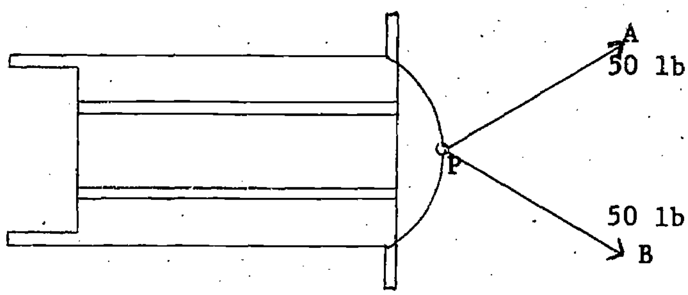

Figure 5

Which one of the following is true?

(12)

A The net force at P = 100 lb.

B The net force at P is NOT equal to 100 lb.

YOUR ANSWER --- B

You are correct. If you cut any one of the strings, thereby removing one of the forces, the particle P would immediately shift its position showing that the force that was removed had been serving as an equilibrant.

NOTEBOOK ENTRY
Lesson 7

(Item 3)

(g) When a system of forces acting on a particle is in equilibrium, any one of the forces may be considered as the equilibrant of the system.

As the next part of our problem dealing with Figure 13 on page 80, suppose we want to know the resultant of forces A and B. Of course, you could determine this by the usual vector triangle method, but as it happens there is a much, much simpler way to find it. If you refer to Notebook Entry 3(d)(1), you should get an unmistakable clue. Applying the idea suggested, which one of the forces should you consider the equilibrant?

(26)

A Force A.

B Force B.

C Force W.

YOUR ANSWER --- C

No, this wouldn't work. Actually, the length of the rope does not play any role in the problem, as long as the angle between the rope and ground is not changed. Shortening the rope would cause the boy to stoop as he applies the force, but it would have absolutely no effect on the components of force.

When yc ew the vector diagram for the sled situation, the length of the rope was not stated, yet you were able to determine the components. This indicates that the length of the rope is irrelevant to the problem.

Please return to page 114 and pick another answer.

YOUR ANSWER --- B

The statement of the problem includes a very important bit of data: if the window were to be opened by a force applied vertically to it, then 75 lb would be just enough to accomplish the job. This is not along the line of the pole.

Look at Figure 28. The vertical component of the pupil's force, F, along the pole must be at least 75 lb. Since the 75 lb vector is one leg of a right triangle of which F is the hypotenuse, then F must be greater than its vertical component. Some of the boy's force will be "wasted" as a horizontal component which tends to pull the window out of its frame.

Scale: 1 cm = 10 lb

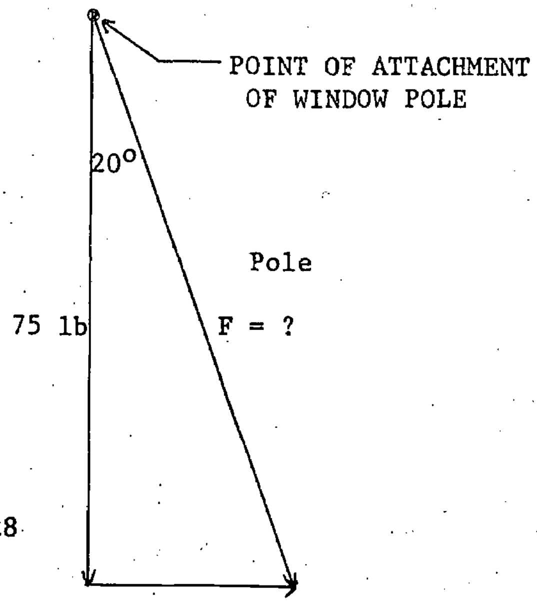

Figure 28

Please return to page 56; you have sufficient information to determine the right answer.

YOUR ANSWER --- C

No, that's not correct. Always draw a rough diagram of the forces, not necessarily to an exact scale but at least approximately. See Figure 18.

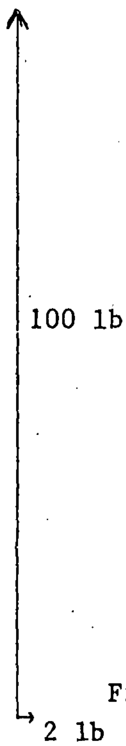

Figure 18

Just to get an idea of the relative sizes of the forces, we have drawn them roughly to scale. Then, if you visualize the kind of triangle formed by moving the 2.0-lb force up to join the head of the 100-lb force, you can easily compare the length of the hypotenuse with both of the other legs of the triangle.

You should be able to recognize your error now.

Please return to page 23 and select a more probable answer.

YOUR ANSWER --- A

The statement of the problem includes a very important bit of data: if the window were to be opened by a force applied vertically to it, then 75 lb would be enough to move it. This is not along the line of the pole.

Look at Figure 28. The pupil pulls along the line of the pole, hence only a part of his force becomes a useful vertical component, the other part being "wasted" as a horizontal component which tends to pull the window out of its frame.

Scale: 1 cm = 10 lb

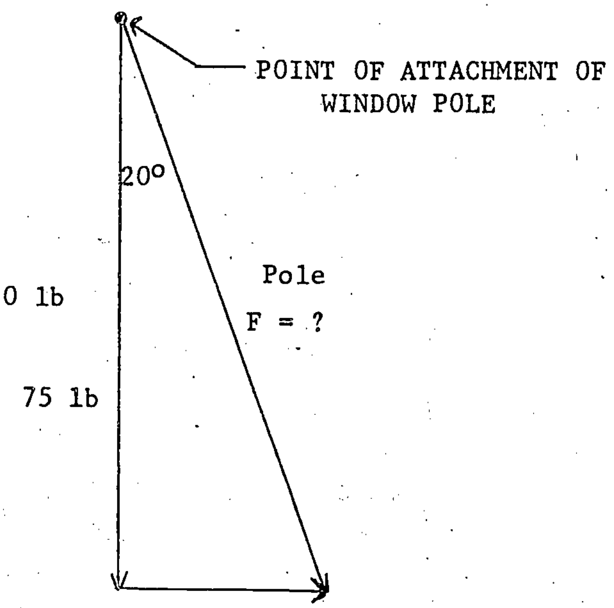

Figure 28

So, if he needs a vertical component of 75 lb, then he would have to exert more than 75 lb along the pole.

Please return to page 56. You have enough information to work out the right answer now.

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YOUR ANSWER --- C

If you used this scale, the 120-lb force would be 1 cm long and the 80-lb force would only be 2/3 cm long. Could you work with any degree of precision using a vector diagram as small as this? Hardly!

Please return to page 39 and choose another answer.

YOUR ANSWER --- A

This situation is depicted in Figure 20. You can see at a glance why your choice of answer was incorrect. Always draw a rough vector diagram to help you answer questions like this.

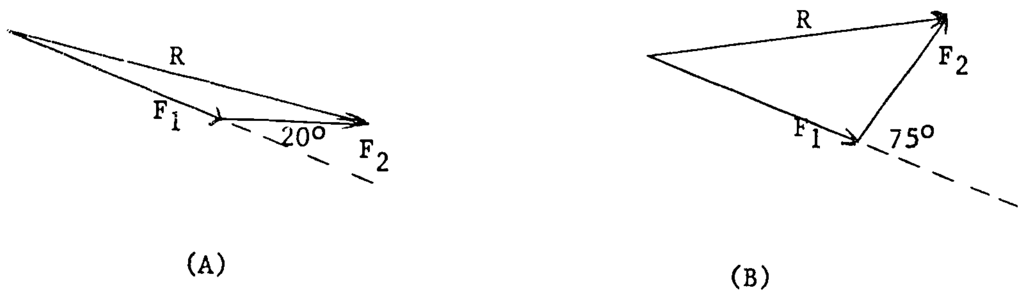


Figure 20

Please return to page 31 and select the right answer.

YOUR ANSWER --- A

This is not a good choice. If one of the arms of the vector triangle is 5 units (according to any scale), and the other arm is 12 units, then the hypotenuse which represents the resultant of the two forces must be greater than 12 units. For a view of the start of the correct vector picture, see Figure 16.

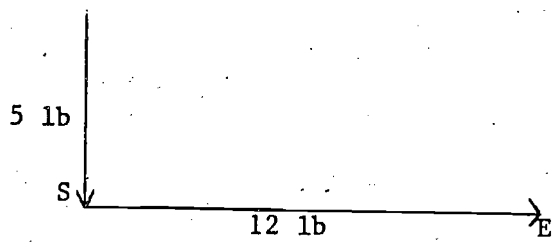


Figure 16

Please return to page 158. Reread the problem and work throu .t one more, if necessary. You should come up with the correct answer.

YOUR ANSWER --- B

You are correct. Figure 27 points out why this is right. As the angle is reduced, a greater portion of the applied force becomes the useful component; less is wasted.

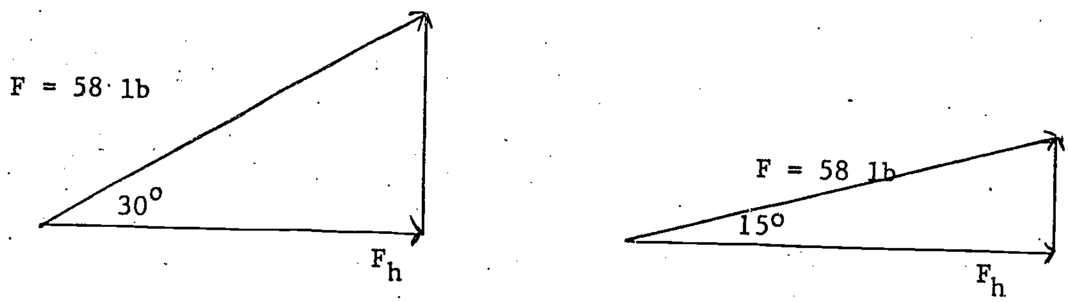


Figure 27

In the same example, at what angle would the rope have to pull on the sled to

(a) obtain the largest possible useful component?
(b) obtain a useful component of zero magnitude?

Write your answers; then turn to page 56.

CORRECT SOLUTION: Weight W = 2.1 tons.

If you had trouble setting up the diagram, be sure you study the steps outlined below so that this difficulty will not recur.

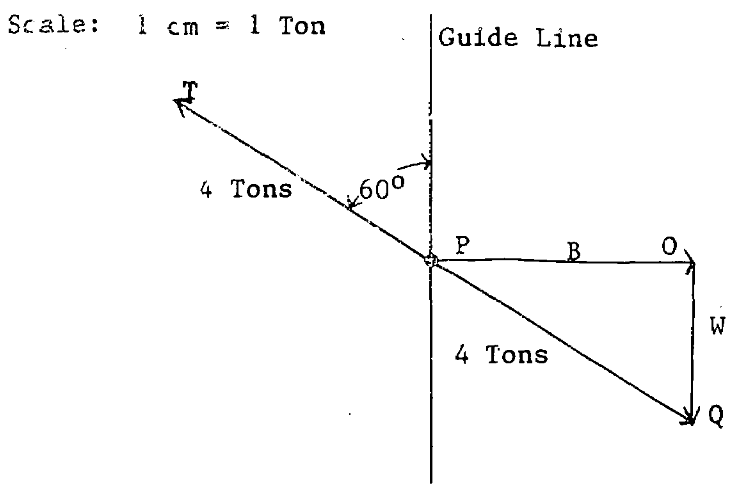


Figure 30

Step 1: Lay out the tension T at 60° to the vertical. Using a convenient scale, adjust the length of the T vector to represent 4 tons.

Step 2: Extend T in the opposite direction. Be sure the length of PQ is the same as that of T.

Step 3: From point Q, drop a perpendicular to the horizontal axis to form line segment OQ.

Step 4: Add the required arrowheads to show the direction of the forces. Measure OQ to scale. This is the weight W, of course.

Please turn to page 167 in the blue appendix.

Figure 31 illustrates one of the most frequently encountered situations in the study of mechanics. An object resting on a straight, slanted surface or an <u>inclined plane</u> tends to roll or slide to the bottom. To simplify our immediate problems, we shall assume <u>zero friction</u> between the object and the plane. Then, for this condition, could the object remain on the plane in the position shown if no external forces are applied to it? (Unless told otherwise, you are always to assume that the experiment is performed on the surface of the earth were normal gravitational forces exist.)

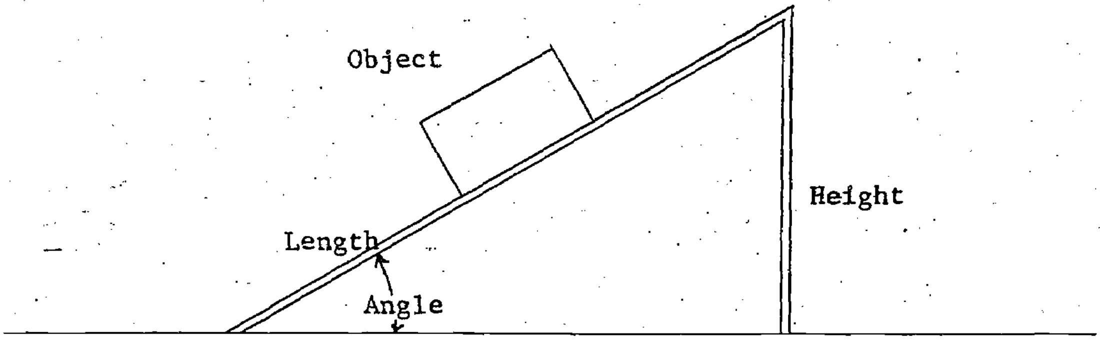


Figure 31

(37)

A Yes.

B No.

YOUR ANSWER --- A

Quite far off.

Check your measurements and redraw the diagram. Be especially careful to make the angle as close to 23° as the accuracy of your protractor permits. You must be precise.

Please return to page 121. Choose another answer on the basis of your new diagram.

YOUR ANSWER --- B

You are correct. The finished drawing is given in Figure 12.

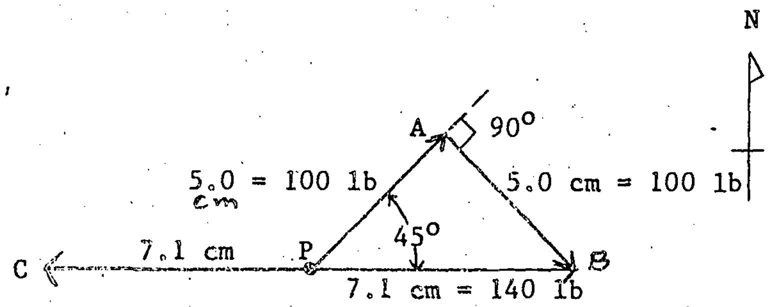


Figure 12

In Figure 12, the resultant force is represented by line segment PB. It is 7.1 cm long and, from the scale 1 cm = 20 lb, we know that it represents a magnitude of 140 lb, to two significant figures.

By the same reasoning as for collinear forces, we know the equilibrant must have the same magnitude as the resultant but be oppositely directed.

Therefore, in Figure 12, what is the magnitude of the equilibrant force, as represented by line segment PC?

(21)

A The equilibrant has a magnitude of 7.1 cm.

B The equilibrant has a magnitude of 140 lb.

YOUR ANSWER --- A

You are correct. For purposes of analysis, we have adopted an unusual but perfectly legitimate approach. Refer to Figure 34 on page 95. We know, of course, that W is the source of F_a and F_b, but we are reversing the picture by thinking of F_a and F_b as the original forces for which W is the resultant. Since this gives us exactly the same vector picture as the true situation, we introduce no error by it.

At this point, our interest lies in determining the magnitudes of both the sliding force F_a and the perpendicular force F_b, knowing the weight W and the angle of inclination of the plane. In Figure 35, we have drawn a relatively complete vector picture of the forces acting on a body resting on a plane whose angle of inclination is 35^o. To keep our thinking straight, we show the forces acting on a particle at the center of the object; also, we draw forces OM and MN in a head-to-tail relationship in the customary fashion, indicating W as the resultant.

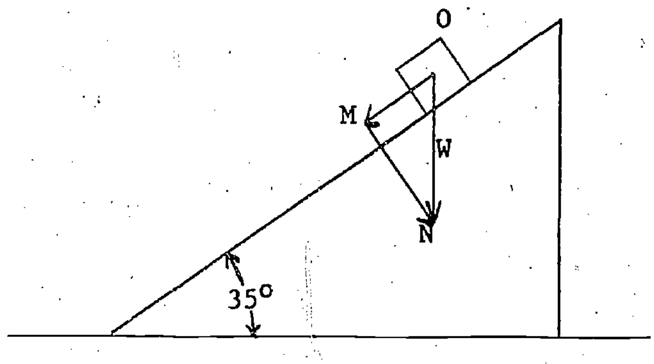


Figure 35

Answer the following question by inspection: for this plane, which is the larger force, the sliding force or the perpendicular force?

Please go on to page 110.

YOUR ANSWER --- C

You are correct. Check your diagram against Figure 37. To solve this problem, you had to draw the diagram very carefully and correctly; it is always important to lay out the angles as correctly as your protractor permits. Note that the sliding component is F_a, and that this turns out to be 8.0 lb. Then obviously the force required to maintain equilibrium is equal in magnitude and opposite in direction. This equilibrium force is shown as F_e in Figure 37.

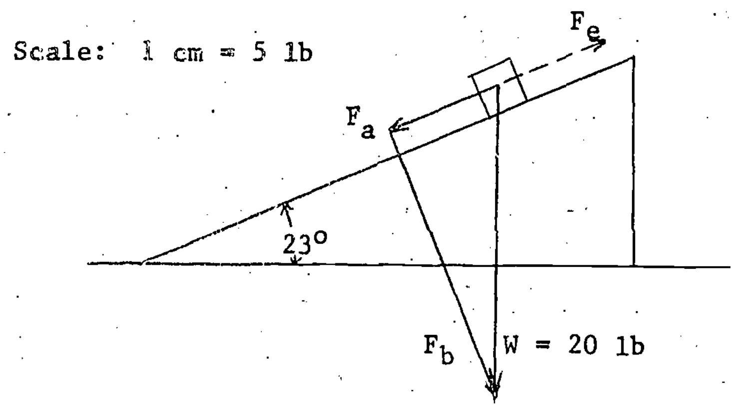


Figure 37

Please go on to page 151.

You have now completed the study portion of Lesson 7 and your Study Guide Computer Card and A V Computer Card should be properly punched in accordance with your performance in this Lesson.

You should now proceed to complete your homework reading and problem assignment. The problem solutions must be clearly written out on 8½" x 11" ruled, white paper, and then submitted with your name, date, and identification number. Your instructor will grade your problem work in terms of an objective preselected scale on a Problem Evaluation Computer Card and add this result to your computer profile.

You are eligible for the Post Test for this Lesson only after your homework problem solutions have been submitted. You may then request the Post Test which is to be answered on a Post Test Computer Card.

Upon completion of the Post Test, you may prepare for the next Lesson by requesting the appropriate

1. study guide
2. program Control Matrix
3. set of computer cards for the lesson
4. audio tape

If films or other visual aids are needed for this lesson, you will be so informed when you reach the point where they are required. Requisition these aids as you reach them.

Good Luck!

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

You are correct. Refer to Figure 13 on page 80. If A and B were arranged so that their strings hung straight down, their forces would be collinear and would add up to the same value as the hanging weight. In the situation in Figure 13 on page 80, part of A's force is wasted pulling to the left and part of B's force is wasted pulling to the right. That is, only a part of A and only a part of B act to support the weight.

The system shown in Figure 13 is in equilibrium since particle P is at rest. We can therefore assume that one of the forces, A, B, or W is acting as the equilibrant for the other two.

Now, think carefully. Which one of the following statements is correct?

(25)

A Force W must be considered as the equilibrant for A and B.

B Any one of the 3 forces may be considered as the equilibrant for the other two.

YOUR ANSWER --- B

You are correct, as the diagrams in Figure 20 illustrate.

(A) (B)

Figure 20

In preparation for a discussion of <u>resolution of forces</u>, we want to remind you of an idea that occupied much of our time in the lesson on VECTORS.

Please turn to page 155.

Consider any given force whose magnitude and direction you know. This force may be thought of as being composed of two or more component forces. Confining ourselves to only two components, we showed this given force could have been the resultant of an infinite variety of components. Figure 21 shows only 4 examples of such an infinite number of possiblities; resultant R is identical in every instance, but in each the components F_1 and F_2 differ in magnitude and direction.

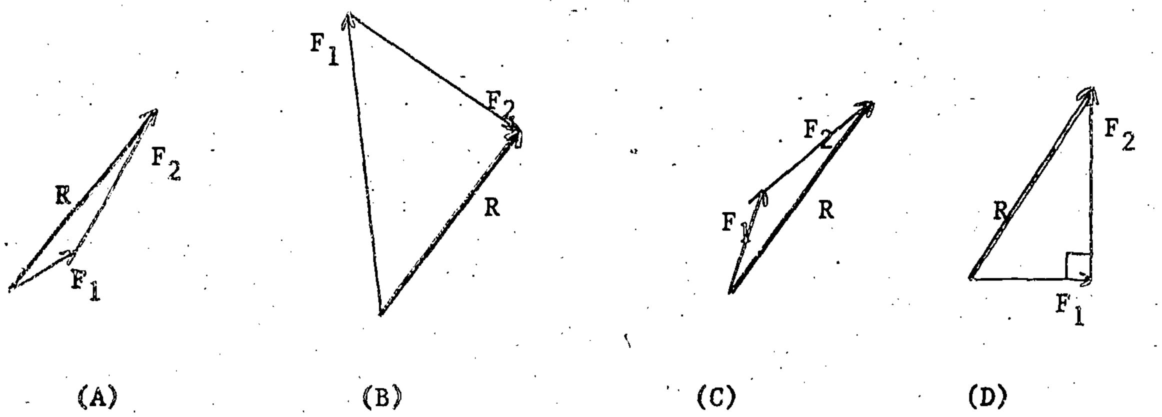


Figure 21

In which one of the four examples are the components called rectangular components?

Please turn to page 24 to check your memory.

YOUR ANSWER --- C

This is incorrect.

The relation between a resultant and an equilibrant is given under topic 3(f), which reads as follows:

(f) If the equilibrant of two or more forces is known, then the resultant of these two or more forces may be taken as equal in magnitude and opposite in direction to the known equilibrant.

Please return to page 94 and choose another answer.

CORRECT SOLUTION: Refer to the diagrams and solution below.

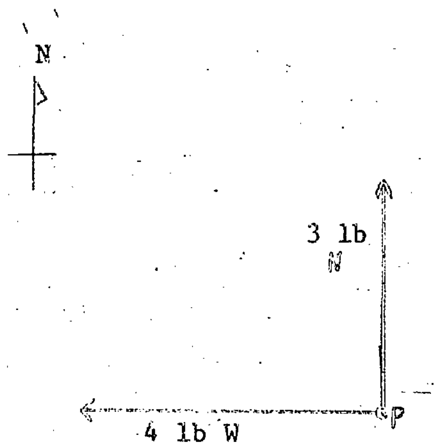


Figure 14

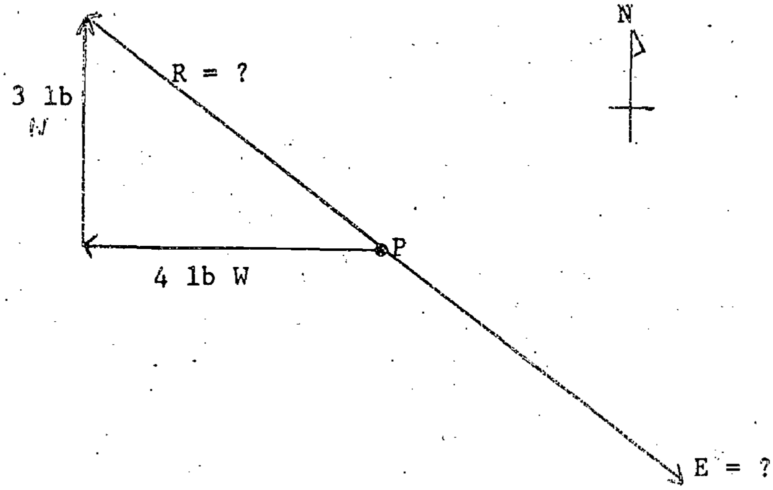


Figure 15

The forces are shown in Figure 14. This is the initial picture illustrating the position of the particle with respect to the forces applied to it. But it is not the vector diagram. To draw the correct vector diagram, it is essential to shift either one of the vectors so that the two are joined head-to-tail as shown in Figure 15. As you see, we shifted the 3 lb N vector, but the same result is obtained by shifting the 4 lb W vector correctly.

The vector triangle is completed by the line segment R. This, of course, is the resultant of the 3-lb and 4-lb forces; its magnitude, from the 3:4:5 triangle, must therefore be 5 lb. The force marked E is clearly a 5-lb equilibrant in the opposite direction.

Please go on to page 158.

All right. Suppose a 5.0-lb S force and a 12.0-lb E force act on the same particle. Find the magnitude and general direction of a single force that will prevent these forces from moving the particle. (Give the answer to two significant figures.)

Select the correct answer from those below.

(27)

A 12 lb northwest.

B 13 lb southeast.

C 13 lb northwest.

D 14 lb northeast.

YOUR ANSWER --- A

You are quite right. Since point P is in equilibrium (being supported by the guy wire and boom), then any one of the three forces may be taken as the equilibrant for the other two.

Thus, we shall consider the tension T (or the force exerted by the guy wire on point P) to be the equilibrant of the system.

All right, refer to Figure 29 on page 115. The tension T acts upward and to the left at an angle of 60° to the vertical. Since we want to find W, we will take B and W as the rectangular components of some resultant force we have yet to find. But this force is easy to determine from the facts given. If T is the equilibrant, don't we therefore know the resultant of B and W? Sure, we do. The resultant of B and W must be a force of the same magnitude as T but opposite in direction.

So, lay out T according to a suitable scale, extend it in the opposite direction to equal vector length, then resolve the resultant thus obtained into B and W.

We want you to work this one out for yourself. No choices are given. Obtain the answer to 2 significant figures.

Then turn to page 145.

YOUR ANSWER --- B

You are not being sufficiently careful in your thinking; you seem to be jumping to a hasty conclusion.

Remember that an equilibrant prevents motion of a particle acted on by other forces. Certainly, the weight of the object, W, as the source of the two components, cannot prevent the body from moving. It is, in actual fact, the prime mover of the system, supplying the sliding force F_a.

Please return to page 95. The other answer is correct.

YOUR ANSWER --- D

This is incorrect.

The method of determining the equilibrant is partly explained in item 3(d)(1) and further described in item 3(e). These two paragraphs read as follows:

(d) The equilibrant in a system of forces is a single force which, when applied to the same particle as the other forces, can maintain the particle in equilibrium.

(1) If a given force system consists of forces A and B acting on a particle, then the equilibrant of this system has a magnitude equal to the resultant of A and B, but has a direction opposite this resultant.

Example: If forces A and B are 3 lb and 8 lb respectively, both directed north, then the resultant is an 11-lb force north. The equilibrant, therefore, is an 11-lb force acting south on the same particle.

(e) To find the equilibrant of two or more forces, first determine the direction and magnitude of the resultant of these forces; then take the equilibrant as equal in magnitude and opposite in direction.

Please return to page 94 and choose another answer.

YOUR ANSWER --- C

This answer is not acceptable. We used a scale of 1 cm = 10 lb as you can see in Figure 25. In measuring the length of the force vector to 2 significant figures, you will find it rather easy to get very close to the right length. However, the angle measurement must be very carefully done; otherwise your answer may go off by quite a large percentage. Perhaps your carelessness lay in your measurement of the angle. Check this again; also, check your vector length measurements.

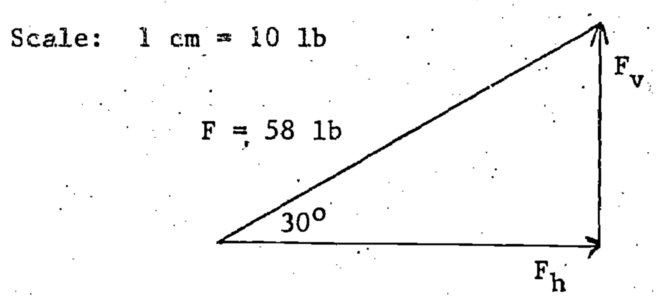


Figure 25

Please return to page 54 and check your measurements. We feel sure that you can come up with a closer answer than the one above.

YOUR ANSWER --- C

This situation is shown in A and B of Figure 20 below. You can see at a glance why the resultant cannot remain the same for an increasing angle. Always draw a rough vector diagram to help you visualize such situations.

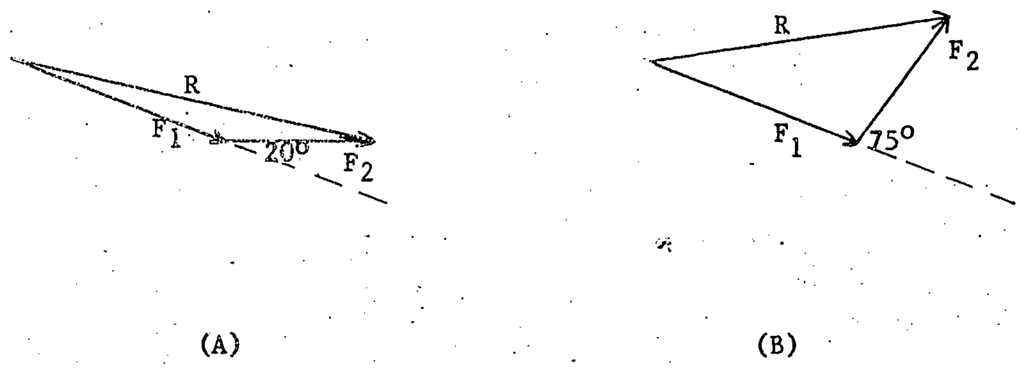


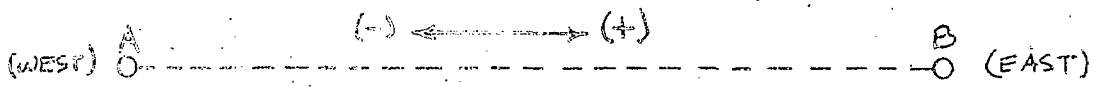
Figure 20

Please return to page 31 and select the right answer.

WORKSHEET

Please listen carefully to tape segment 1 for this lesson before starting this Worksheet. Your answer selections are to be punched out on the AV Computer Card for this lesson.

DATA ITEM A. Starting point: A. Heading horizontal from west to east toward B on the joining line. Ant stops initially 8 cm from A, then heads back toward A along same line and comes to rest 5 cm to the east of A.



QUESTIONS (Ant Problem)

1. The two separate displacements of the ant should be considered to be

   A equivalent.
   B congruent.
   C concentric.
   D collinear.
   E none of these.

2. The vector sum of the two displacements is

   A 11 cm.
   B 5 cm.
   C -11 cm.
   D -5 cm.
   E 13 cm.

3. What is the resultant displacement of the ant at the end of the complete trip?

   A 11 cm.
   B 5 cm.
   C -11 cm.
   D -5 cm.
   E 13 cm.

4. The second displacement is best described as

   A 3.00 cm.
   B 3 cm.
   C -3 cm.
   D 0.03 m.
   E -300 mm.

(next page, please)

5. Assuming the same initial displacement, what magnitude and direction would the second displacement have to have in order to yield a zero resultant?

A -8 cm.
B 8.0 cm.
C -5 cm.
D 5 cm.
E 11 cm.

6. Assuming the same initial displacement, what magnitude and direction would the resultant have had if the second displacement had been + 4 cm?

A -4 cm.
B +4 cm.
C +7 cm.
D -7 cm.
E +12 cm.

Please return now to Tape Segment 1 before continuing with this Worksheet.

DATA ITEM B: Velocity of the stream = 5 mi/hr west to east. Velocity of the boat relative to water = 5 mi/hr, heading south to north.

QUESTIONS (Boat Problem)

7. The direction of the boat's apparent motion as seen by an observer on a raft drifting straight downstream near the problem boat would be

A northeast.
B southeast.
C east.
D south.
E north.

8. In what direction would the boat appear to move to an observer on the south bank?

A northeast.
B southeast.
C east.
D south.
E north.

(next page, please)

9. What is the speed of the boat with respect to the observer on the south bank?

A Less than 5 mi/hr.
B More than 5 mi/hr.
C Exactly 5 mi/hr.
D Data is insufficient to choose one of above.
E Could not be computed with any data.

10. If the speed of the stream were to double, the speed of the boat relative to an observer on the north bank would

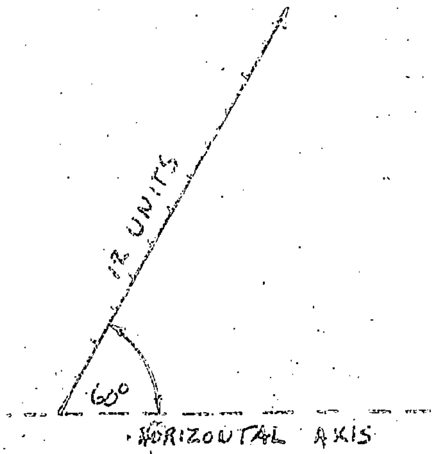
A increase.
B decrease.
C remain the same.
D not be calculable since data is insufficient.
E not be calculable even with more data.

11. The boat changes its heading in the 5 mi/hr stream so that its speed relative to the observer on the north bank is 10 mi/hr. What is the new direction of the boat?

A North.
B South.
C Northeast.
D Northwest.
E East.

Please return now to Tape Segment 1 before continuing with this Worksheet.

DATA ITEM C: See diagram below.



12. Into how many possible pairs of components could you resolve the vector in the diagram?

A None.
B One pair.
C Two pairs.
D An infinite number.
E Insufficient data.

(next page, please)

13. What is the magnitude of the horizontal component of the vector in the diagram on the previous page?

A 12 units.
B 8 units.
C 6 units.
D 24 units.
E 10 units.

14. What would happen to the vertical and horizontal components of this vector if the designated angle were reduced in size?

A Both components would grow larger.
B The vertical component would grow larger but the horizontal component would shrink.
C The horizontal component would grow larger but the vertical component would shrink.
D Both components would shrink.
E Insufficient data.

Now please return to page 4 of the STUDY GUIDE to continue with Lesson 7.

WORKSHEET

Listen to tape segment 2 before proceeding. Use Computer Card.

QUESTIONS

15. Two collinear forces, one of 4 lb and the other of 7 lb are applied to a particle at an angle of 23 degrees to the x-axis. To maintain the particle in dynamic equilibrium,

A we need apply no other forces to it.
B a 4 lb and 7 lb force must be applied at 90 degrees to the first pair.
C an 11 lb force may be applied at right angles to the first pair.
D an 11 lb force may be applied at an angle of 203 degrees to the x-axis.
E two separate 4 lb and 7 lb forces must be applied at 180 degrees to the x-axis.

16. An object moves equal distances in equal times, neither gaining nor losing any speed as it does so. It is in dynamic equilibrium

A provided that it is moving in a straight line.
B regardless of the nature of its path.
C provided its mass does not change.
D for the reasons given in both A and B.
E for the reasons given in all three answers (A, B, and C)

17. A satellite, moving at constant speed in a perfectly circular orbit around the Earth

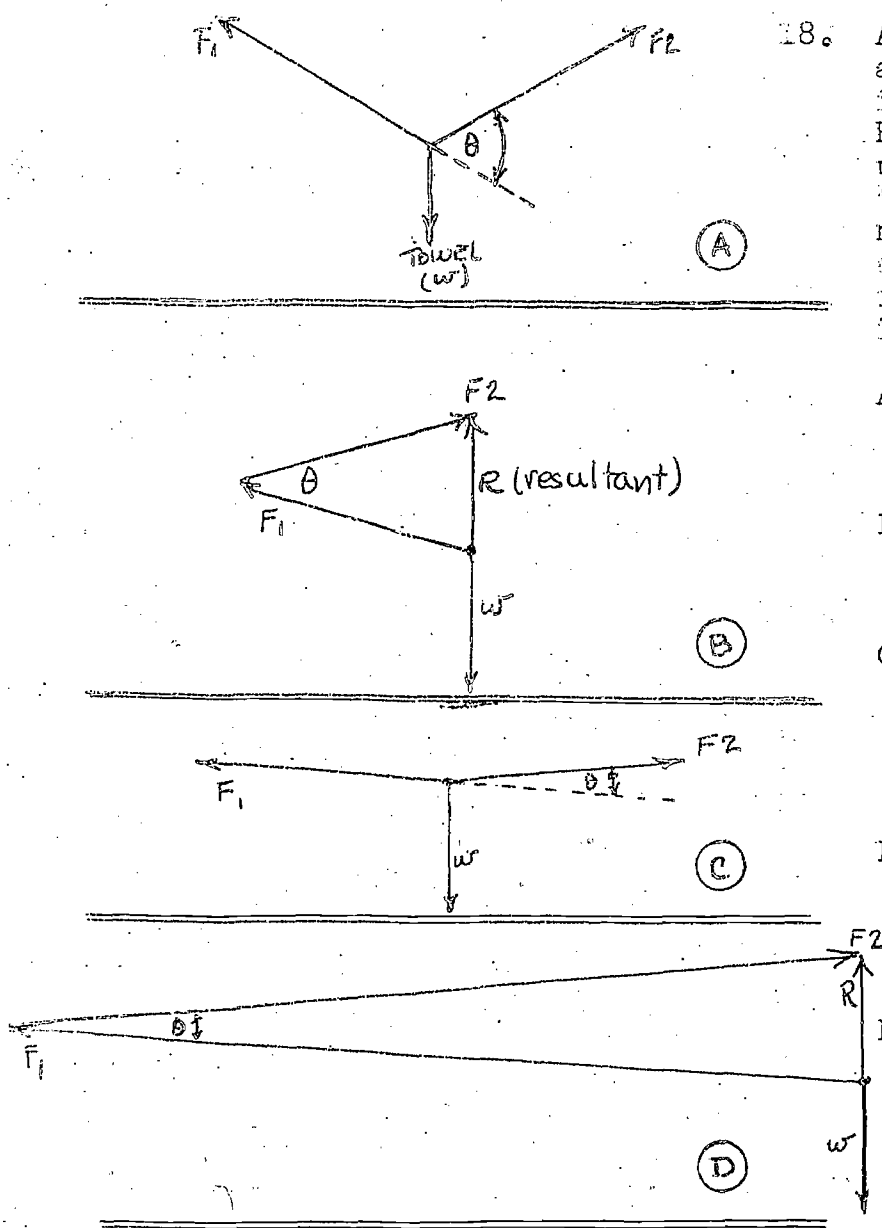
A is in dynamic equilibrium because its velocity is constant.
B is in dynamic equilibrium because there are no unbalanced forces acting on it.
C is not in dynamic equilibrium because there is a tangential force acting on it.
D is not in dynamic equilibrium because there is an outward force acting on it.
E none of the above answers is correct.

Please return to page 112 of the STUDY GUIDE to continue with Lesson 7.

WORKSHEET

Listen to tape segment 3 before proceeding. Use Computer Card.

DATA ITEM A: See diagrams A through D below.



QUESTIONS

18. A radio amateur is installing a transmitting antenna 132 ft in length between two towers. He has a powerful turnbuckle which enables him to tighten the wire of the antenna as much as he wishes. Which one of the following statements relating to this situation is the true one?

A. By using enough force, he can remove all slack from the antenna wire.

B. If he attempts to remove all slack, the antenna wire will break.

C. As he applies more force by means of the turnbuckle, the wire will stretch but will ultimately straighten out completely.

D. Since there is nothing hanging from the wire of the antenna, he will not need much force to remove all slack.

E. No matter how much force he uses, the slack at the center of the wire will never be less than 10% of the wire's length, that is, about 1.32 ft

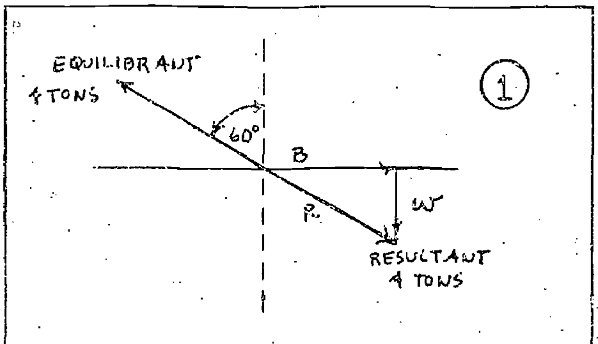
Please return to page 61 of the STUDY GUIDE
to continue Lesson 7.

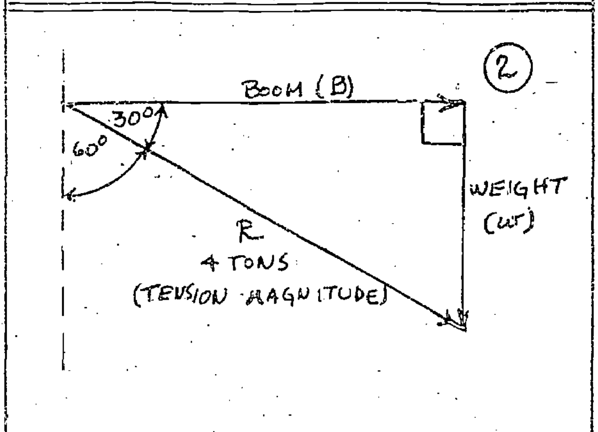
WORKSHEET

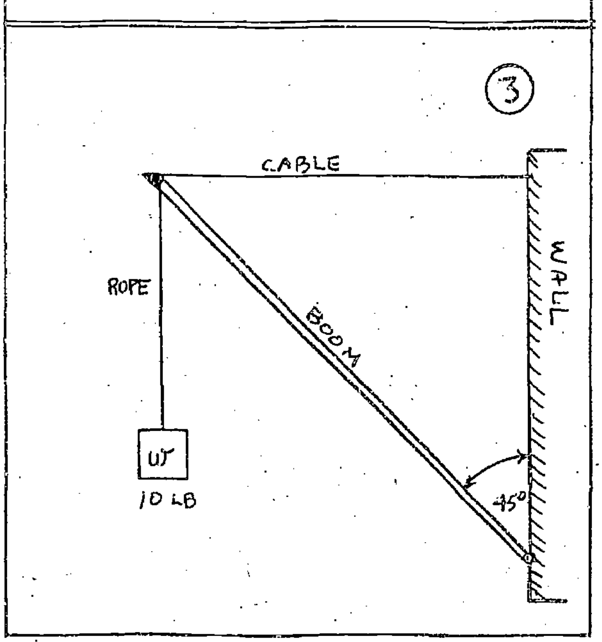
Listen to tape segment 4 before proceeding. Use Computer Card.

DATA ITEM A: Diagrams 1 and 2 below.

DATA ITEM B: Diagram 3 below. All the questions refer to this diagram.







19. Select the one true statement:

    A The thrust of the boom may be considered as the resultant of the weight and cable tension.

    B The cable tension may be considered to be the resultant of the boom's thrust and the weight.

    C If the weight were to increase to 100 lb, the cable tension would remain the same.

    D The thrust of the boom may be considered to be the equilibrant of the system.

    E The tension in the cable cannot be considered to be the equilibrant of the system

20. The tension in the horizontal cable is

    A 14.1 lb
    B 10 lb
    C 7.07 lb
    D 20 lb
    E 22 lb

21. The force exerted by the boom on the point where the rope is tied is

    A 14 lb
    B 10 lb
    C 7.1 lb
    D 20 lb
    E 22 lb

Please return to page 146 now to complete the Lesson.

AMP LESSON 7

HOMEWORK PROBLEMS

Lesson 7

1. A force of 30 lb and a force of 40 lb are applied to the same point on a heavy object. When the angle between the two forces is 90 degrees, (a) what is the magnitude of the resultant force; (b) what is the magnitude and direction of the equilibrant for the two given forces?

2. What is the magnitude of the equilibrant of two 23.7 lb forces acting on the same particle when the angle between the forces is 180 degrees?

3. Four forces of 10 lb each act on a single point on a body. The directions of the forces are north, northeast, due east, and southeast. Determine graphically the direction and magnitude of the resultant. (Express the direction in degrees east or west of north.)

4. A worker pulls a crate across a floor by means of a rope that makes an angle of 60 degrees with the horizontal floor. If the force applied by the worker along the rope is 12 lb, (a) what is the horizontal component of his applied force; (b) what is the vertical component?

5. A gardener pushes a lawnmower by applying a force of 30 lb to the handle. What is the useful component of this force when the lawnmower handle makes a 45 degree angle with the ground?

6. A car weighing 1500 lb rests on a 15 degree hill. Determine the components of the car's weight (a) at right angles to the hill surface; (b) parallel to the hill.

7. A weight of 50 lb is hung from the center of a stretched wire 10 m long. The weight causes the initially horizontal wire to sag 1 m at the center. What is the tension in either of the two halves of the wire?

8. A pendulum is assembled using a string 1 ft in length and a bob weighing 1 lb attached to the lower end of the string. As the pendulum swings to its highest point on either side, the string makes an angle of 30 degrees with the vertical. Find the tension in the string when the pendulum is at the highest point of its swing.

9. A car is stalled in mud. In an attempt to pull it out, the driver ties one end of a rope to the car and the other end to a tree 100 ft ahead of the car. He then grasps the rope at its midpoint and pulls it 3.0 ft sideways with a force of 80 lb. How great a pulling force will this exert on the car?

Please follow the rules previously stipulated for problem solution and submission.