



Lab 3:

The Sum of Vectors



Lab

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Goals

1. To become aware that at equilibrium, the sum of balanced forces is zero
2. To graphically find the sum of vectors
3. To find the vertical and horizontal components of vectors
4. To calculate the sum of vectors using the vertical and horizontal components
5. To gain a better understanding of mechanical equilibrium

Materials and Equipment

Two 250 g spring scales
String
Slotted mass set

Material Not Included

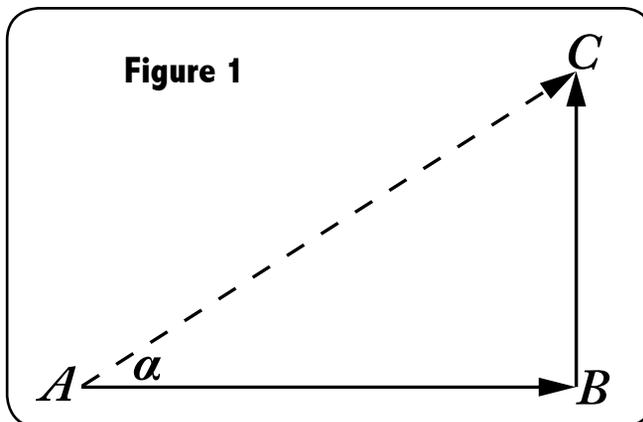
Graph paper
Protractor
Masking tape
Card Table or small table

Introduction

Scalar quantities are completely specified with only a number and a unit. I.e., scalars have magnitude but not direction. Examples are mass, volume, and area. Adding scalar quantities, assuming they are compatible, is simple. For example, two liters plus five liters gives seven liters.

A **vector** is a quantity that has both magnitude and direction. Examples are displacement, force, velocity, and magnetic fields. Since vectors have magnitude and

direction, adding vectors is usually more complex than adding scalars. The sum of two vectors is the **resultant**.



Displacement is the change in position. This is a vector since it has both magnitude and direction. If you walk three blocks east and then two blocks north, your displacement will be from your starting point to your ending point. The walk east and the walk north are two displacements that form the legs of a right angle triangle and the resultant is the hypotenuse. (You may need to go through some houses if you walk the resultant.) See Figure 1. Using trigonometry, angle α is:

$$(1) \text{ angle } \alpha = \text{tangent}^{-1} \frac{2}{3} = 33.7^\circ$$

The magnitude of the displacement can be found using trigonometry.

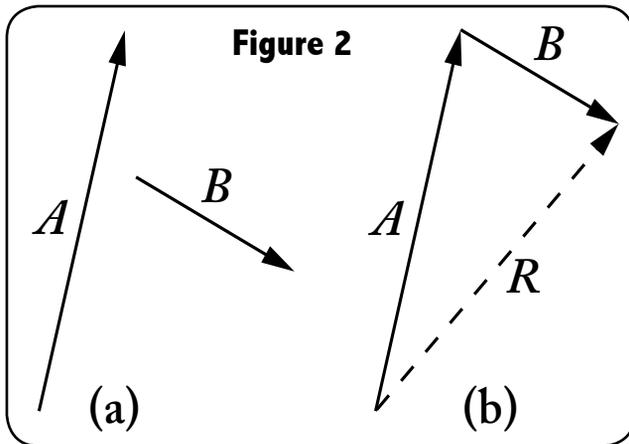
$$(2) \sin \alpha = \frac{BC}{AC}$$

Rearranging this

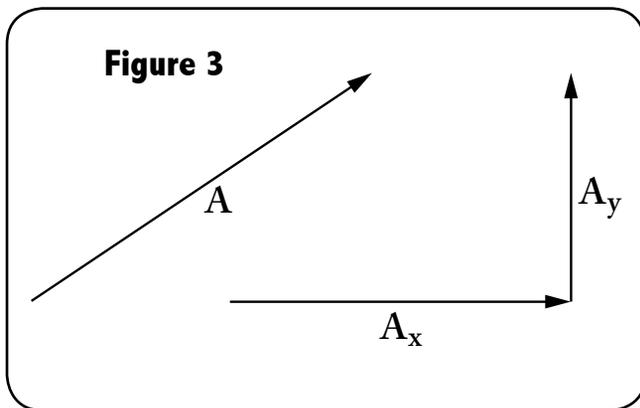
$$(3) AC = \frac{BC}{\sin \alpha} = \frac{2}{\sin 33.7^\circ} = 3.6 \text{ blocks}$$

A vector can be moved if the direction and magnitude are not changed. In

Figure 2(a) below, there are two vectors with different magnitudes and different directions. If they are moved so that the head of vector A is at the tail of vector B, the resultant, R, is from the tail of vector A to the head of vector B. See Figure 2(b). This method will be used to add vectors graphically. The addition process can also be reversed to find the vertical and horizontal components of vectors.



The addition process can also be reversed to find the vertical and horizontal components of vectors. See Figure 3. Vector A is equal to the sum of vectors A_x and A_y . Therefore, vector A can be converted to horizontal component A_x and vertical component A_y .



Note: Your spring scales correctly measure force in newtons, but also show the equivalent mass in grams.

Devotional

“Is any one of you in trouble? He should pray. Is anyone happy? Let him sing songs of praise. Is any one of you sick? He should call

the elders of the church to pray over him and anoint him with oil in the name of the Lord. And the prayer offered in faith will make the sick person well; the Lord will raise him up. If he has sinned, he will be forgiven.” James 5:13-16

“Come to me, all you who are weary and burdened, and I will give you rest. Take my yoke upon you and learn from me, for I am gentle and humble in heart, and you will find rest for your souls. For my yoke is easy and my burden is light.” Matthew 11:28-30

Principle: Peace is not absence from pressure, it is pressure in balance.

The vector sum of the forces = (mass) x (acceleration)

Objects are accelerating when the sum of all forces is not zero. Objects are at rest when the sum of all forces is zero. Notice, this does not say that objects at rest experience no force. No, objects at rest do experience forces. In fact, engineering students will take a whole class called statics which analyzes the forces on an object at rest.

When we are at rest and doing well, it is not because we have no difficulties or conflicts. We will always have difficulties and conflicts in this life. When we are rest and doing well, it is because we have learned to balance and process the difficulties. We are confessing our sin and finding cleansing from God. We are gaining strength by proper rest for our body and soul. We are taking time with God, our refuge in storms. If our lives get out of balance, we must seek God and apply force against these unbalanced forces. This is how to be at rest. The reason Jesus “burden” is light is because the forces are in balance. While the tasks may be great, the burdens are largely carried by God himself.

Procedure

1. Use the slotted mass set to calibrate the two spring scales.
2. If using a card table, open up the

table legs. Place the table on end so that the legs are horizontal and the top is vertical.

Note: As an option, you could use suction cups on a smooth surface to support the scales. Position the suction cups about 1 m apart, attach the spring scales, then continue with Procedure 4.

3. Fasten the scales to the right and left legs of the table with string. See Figure 4.

4. Tie a string between the scales so that the angle between them is about 100 to 130 degrees.

5. Tie a short string to the first string, but slightly off center.

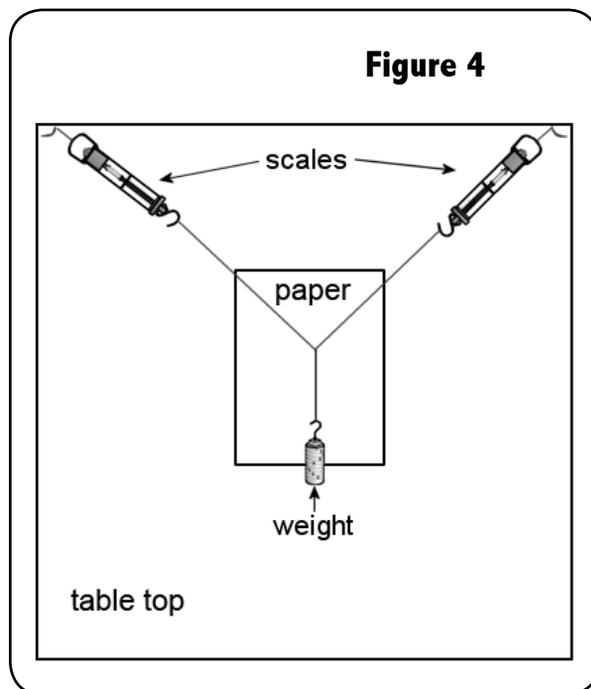
6. Weigh the mass holder with all the masses (250 g total mass) in newtons and record this weight (force). Fasten the mass holder with all the masses to the string.

7. Tape a sheet of graph paper to the table under the strings so that the lower string is parallel to the graph lines.

8. Label the vector that points up and to the right A, the vector that points up and to the left B, and the vector that points down C. See Figure 5.

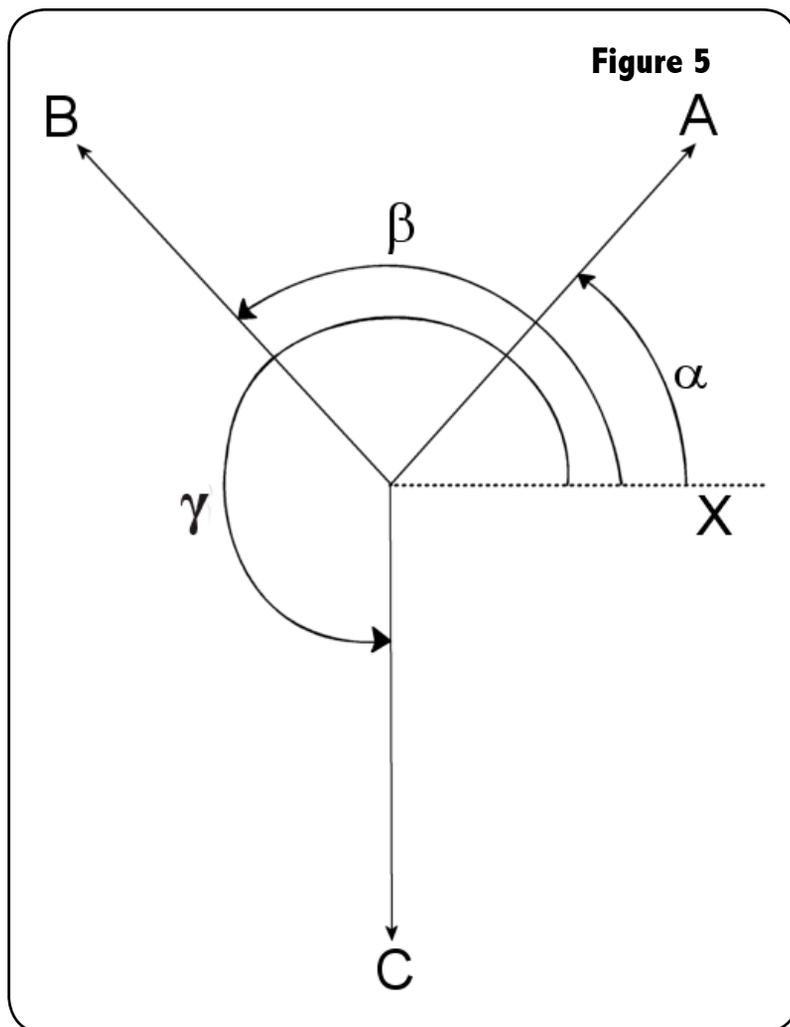
9. Mark the graph paper under the strings to indicate their directions. Be careful not to move the strings. Read the scales (in newtons). Record the forces in Table 1. **Note: The weight of 1 g = 0.00981 N.**

10. Remove the graph paper from the table top. This will have some data that you will need.



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Questions for the Sum of Vectors



Table 1

| Vector | Magnitude, N | Direction, degrees | Horizontal component, N | Vertical component, N |
|---------------|---------------------|---------------------------|--------------------------------|------------------------------|
| A | | | | |
| B | | | | |
| C | | | | |
| Sums | XXXX | XXXX | | |

1. The weight of the 250 g mass _____ N.
2. Use the protractor to measure the angles between vectors A, B, and C and the x axis (horizontal axis). (See Figure 5.) Record these.
3. From the angles and the magnitudes of the angles, calculate the horizontal and vertical components of the three vectors. Record these data in the table. Consider up and right to be positive and left and down negative.
4. Add the horizontal and vertical components and record these sums in the table.
5. With perfect measurements, the sum of the vertical components in the table would be zero. What is the percent difference between the vertical components vectors of A and B and the weight of the 250 g mass?
6. Draw the sum of the vectors to scale on a piece of graph paper. Does the sum come to a point (i.e. is the sum zero)?



Lab 22: Resistors


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Goals

1. To become familiar with an electronic breadboard
2. To gain experience with a breadboard by making simple circuits
3. To become familiar with the color code for resistors

Materials and Equipment

Breadboard
 Multimeter
 Needle nose pliers
 Resistors: 2.2 k Ω , 4.7 k Ω , 10.0 k Ω

Note: *k* = X 1 thousand, *m* = X 1 million

Introduction

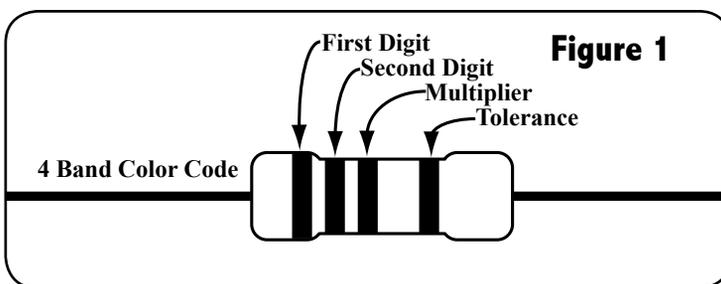
A **resistor** is a device that impedes the flow of an electrical current. Resistors are used in essentially all electronic devices. The value of many common resistors can be

Table 1

| Color | Digit | Multiplier |
|--------|-------|-----------------|
| Black | 0 | X 1 |
| Brown | 1 | X 10 |
| Red | 2 | X 100 |
| Orange | 3 | X 1000 |
| Yellow | 4 | X 10,000 |
| Green | 5 | X 100,000 |
| Blue | 6 | X 1,000,000 |
| Violet | 7 | X 10,000,000 |
| Gray | 8 | X 100,000,000 |
| White | 9 | X 1,000,000,000 |

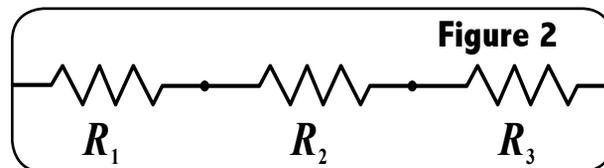
determined by their color code. Table 1 gives the common color code scheme.

With a four band color code, the first and second color band indicates the first two digits and the third band is the multiplier. The fourth band gives the tolerance with



silver indicating 10 %, gold indicating 5 %, and red indicating 2 %. If it is difficult to read the colors, the resistance should be checked with a multimeter.

In a series circuit, the current has only one path and must flow through several resistors in succession. The current will be the same through each resistor. However, the voltage across the resistors may not be the same. Figure 2 gives an example of a circuit diagram of a series circuit.



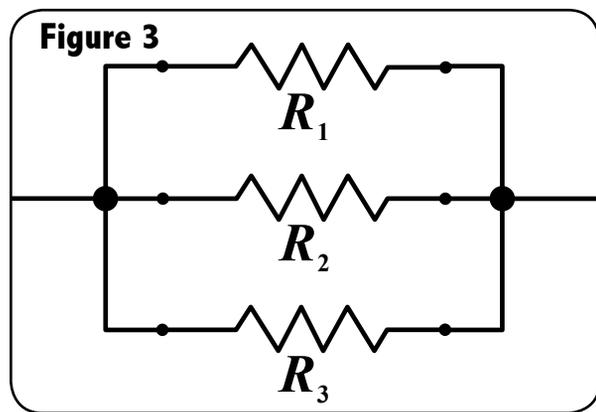
The sum of several resistors in series is found by simply adding their values. That is:

$$(1) R_{total} = R_1 + R_2 + \dots R_n$$

If the values of R_1 , R_2 , and R_3 are 47 Ω , 75 Ω , and 163 Ω , respectively, the sum is:

$$47\Omega + 75\Omega + 163\Omega = 285\Omega$$

Parallel resistors are arranged so that the current splits and is divided between several resistors. The total current is thus the sum of the currents through each resistor. The voltage will be the same across each resistor. Figure 3 shows a circuit diagram of parallel resistors.



The sum of a set of parallel resistors is the reciprocal of the sum of the reciprocals of the resistor values:

$$(2) \frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

where R_{total} is the sum of the resistors and $R_1, R_2,$ etc. are the values of the individual resistors. If the values of these resistors are $47\Omega, 75\Omega,$ and $163\Omega,$ respectively, the total is:

$$\frac{1}{R_t} = \frac{1}{47\Omega} + \frac{1}{75\Omega} + \frac{1}{163\Omega} = 0.0407\Omega^{-1}$$

The reciprocal of this is:

$$R_{total} = 24.6\Omega$$

This is easier done on a calculator that has a reciprocal function.

Devotionals

"For he chose us in him before the creation of the world to be holy and blameless in his sight. In love he predestined us to be adopted as his sons through Jesus Christ, in accordance with his pleasure and will..." Ephesians 1:4-5

Principle: An organized life is a life lived better.

An electric breadboard is a helpful tool to organize and put together electric circuits. In fact, electronic circuit boards, like the breadboard used in this lab, are used everywhere in the electronics industry to make electronic controls and functions. The boards organize the components and give a far greater variety of functions than the individual components can achieve on their own.

Organizational tools are helpful in all of life. If you want to know where your money goes, you can make a budget. If you want to know when you will graduate from high school, you make a schedule of courses you need. If you want to get your homework done on time, you schedule your work.

God himself is a planner. He planned history. He planned for you to exist. Believers are told that God thought about us before the beginning of world. God has future plans for us to purify us and bring us to be with him.

Planning does take time. But the benefits completely outweigh the cost of time. Organizing and planning is useful. It is God's way to do things and he has set an example for us. To be successful, as God is successful, you need to plan.

Procedure

Note: If you have not done Lab 20: Capacitors yet, please read the section Introduction to the Breadboard at the beginning of that lab.

1. Take a 2.2 kΩ, a 4.7 kΩ, and a 10.0 kΩ resistor out of their respective packages. Use pliers to shorten the leads on these resistors to about 10 mm.

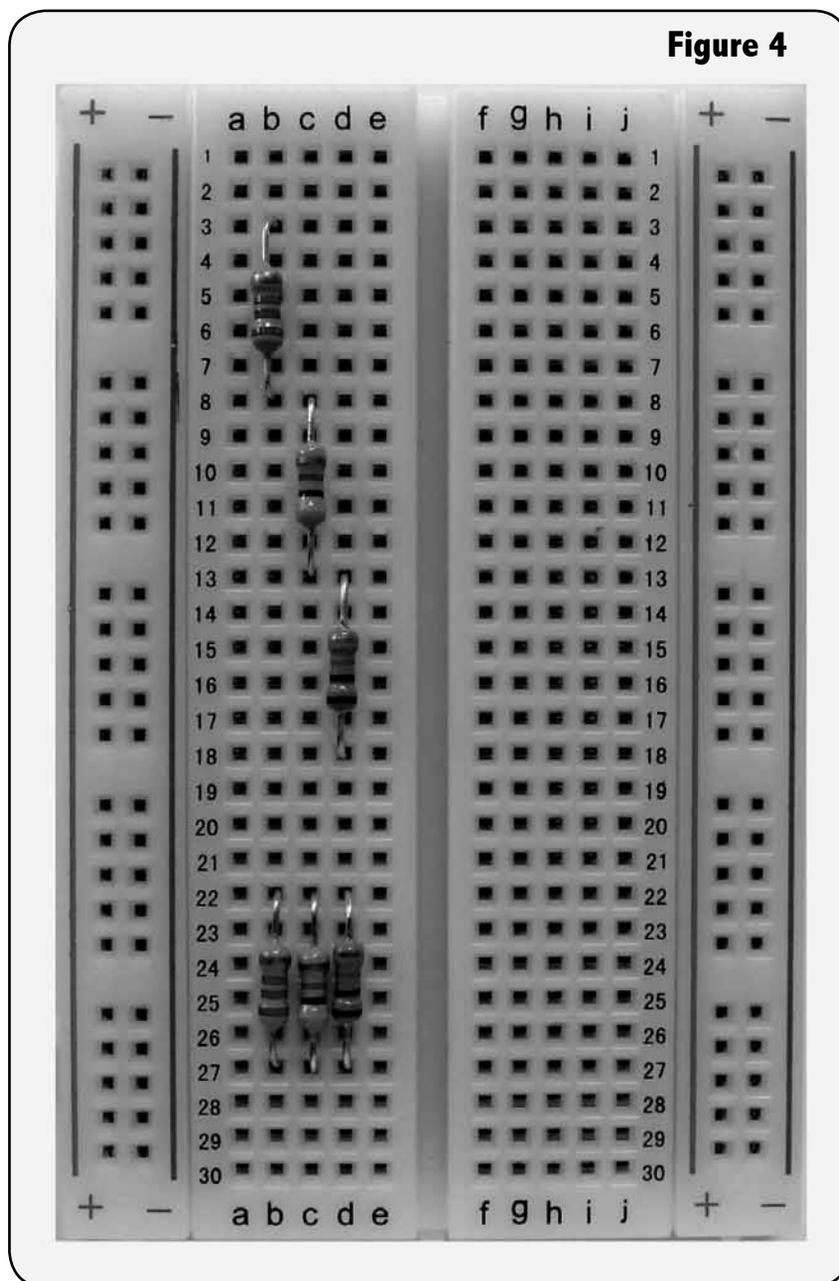
2. The 2.2 kΩ resistor has three red bands and a gold band. From the color code, the first two red bands indicate 22 and the third band indicates X 100. This gives a 2200 Ω or 2.2 kΩ resistance. Examine the two other resistors and fill in Table 2 in the questions section.

3. Bend the leads of the first resistor and insert them in the 3b and 8b positions. Insert the leads of the second resistor in the 8c and the 13c positions. Since there is a bus under the 8a through the 8e positions, these positions are connected electrically and two resistors are in series. Put the leads of the third resistor in the 13d and the 18d sockets. Again, there is an electrical bus under the 13a through the 13e sockets and the second and third resistors are in series with the first resistor. See the upper portion of Figure 4.

4. Take a second set of 2.2 k Ω , 4.7 k Ω , and 10.0 k Ω resistors and shorten the

leads like you did in Procedure 1. Put the first of these in the 22b and 27b sockets, the second in the 22c and 27c sockets, and the third in the 22d and 27d sockets. The board should look like the lower portion of Figure 4. The ends of the resistors in row 22 a through e will be connected and the ends of the resistors in row 27 will similarly be connected. These resistors are in parallel.

5. Fill in the answer in the questions section. Save the wired breadboard for Lab 22.



Lab 22

Questions for Resistors

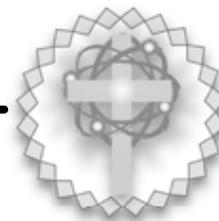


Table 1

| Resistor | Band colors | Digits | Multiplier | Resistance value |
|----------|---------------------|--------|------------|---------------------------------|
| R1 | Red, red, red, gold | 22 | X 100 | 2200 Ω or 2.2 k Ω |
| R2 | | | | |
| R3 | | | | |

Table 2

| Circuit | Measured sum, Ω | Calculated sum, Ω | Difference, % |
|----------|------------------------|--------------------------|---------------|
| Series | | | |
| Parallel | | | |

1. Use the multimeter to measure the resistance of this series combination. Turn the meter on and turn the control to the ohms (Ω) position. Touch one meter probe to the lead in the 3b position and the other probe to the lead in the 18d position. Record this in table 2.

2. Use equation 1 to calculate the resistance of the series circuit. Does the meter (Procedure 4) agree with the calculated value? Calculate the percent difference. The resistors have a 5% tolerance. Is the difference within 5%?

3. Measure the sum of these resistors by touching one probe to a lead in row 22 and the other probe to a lead in row 27. Record this in Table 2.

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4. Calculate the resistance of the parallel circuit. Calculate the percent difference between the measured value and the calculated value. Is this within 5%?

