ARISE – Physics First – Topics to Consider

Topic 1: Vectors – (a) Displacement (First Example)

Source: *Conceptual Physics*, Paul G. Hewitt, 3rd Edition, Chapter 3 (Sections 3.1, 3.2, 3.3) and the *Conceptual Physics Laboratory Manual*

Types of Materials: Textbook, laboratory manual, demonstrations, worksheets and activities

Building on: Define physical quantities with examples of scalars and vectors. To start the study of the abstract vector idea, we start with displacement using a graphical approach. One worksheet, one activity and one lab will start the exploration process.

Leading to: After the introduction of displacement as one vector example, the next vector introduced is velocity, followed by force, to show that many physical quantities are vectors. The introduction of different vectors at this point is NOT for mastery, but to have students begin recognizing the presence of vectors in everyday situations.

Links to Physics: As the student studies topic after topic, almost all have vector applications. Just to mention a few to make a point: displacement velocity, acceleration, force, momentum, torque, electric fields, magnetic fields, and so it goes. Once the vector concept is worked with, time and again, this topic will become commonplace.

Links to Chemistry: Vectors are generally thought of in physics, mathematics and engineering. However, vectors are in the understanding of some chemistry concepts but are behind the scenes. For example, displacement does occur when atoms of a gas like air bump into each other. The average distance between collisions is called mean free path. For non-moving air, no preferred direction would result, but for one individual path, a given direction in space does occur.

Links to Biology: Again, in biology, vectors are behind the scene, but displacement is occurring when an animal runs south. As in chemistry, vector concepts are not needed in many introductory topics, but are there behind the scenes.

Materials:

(a) Hewitt – Lab 15 – Riding with the Wind

(b) Hsu*

(c) Activities
C-1: Pre-Vector Discussion

C-2: Walking Vectors

(d) Worksheet – Vector Practice Worksheet

(e) 1. Demonstration – Step Vectors
2. Vector Miscellaneous (a, b, c,)

(f) Websites and Videos

1. Mechanical Universe Video – "Vectors"
   (Captain Duke and crew lost at sea on good ship Irish Coffee)
   http://www.learner.org/resources/series42.html

2. Sailing Vector Lab Sim (Shockwave)
   (Animated interactive lab simulation)
   http://www.macromedia.com/shockwave/download/download.cgi?P1ProdVersion=ShockwaveFlash

3. This entry is appropriate for *all* topics in this supplement guidebook. The *videos* cover all aspects of physics in *demonstration* form. They are called, "The Video Encyclopedia of Physics Demonstrations" by The Education Group. They have one sample online that looks good and it is brief. The set of 25 DVD's with 10 hours of play is $2,995.

4. Science School House is interactive on the computer on most all physics topics (E&M, heat, mechanics, sound and waves, light in both video and software). Gives details and prices.
   http://www.scienceschoolhouse.com/school/catalogue/physics/videos

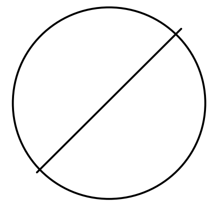
(g) Good Stories – Direction

Topic 1: C-1 – Pre-Vector Discussion

The purpose of this discussion with students is to begin an understanding of an abstract concept such as a vector by using familiar examples. Daily situations use abstractions as well as math in a classroom setting, so it is hoped that this discussion will begin the understanding.

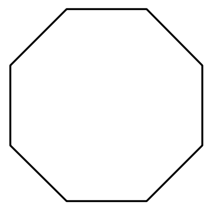
(a) First discussion: What does this symbol mean?

(NO for whatever is at the center of the circle; e.g., a swimmer in dangerous water, no passing on a highway, etc.)



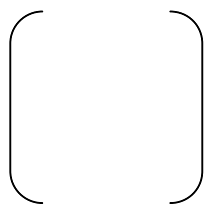
(b) What does this symbol mean?

(Stop Sign)



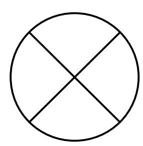
(c) What does this symbol mean?

(Double bracket to show all items within are included)



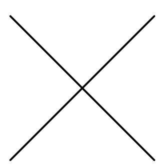
(d) What does this symbol mean?

(Railroad Crossing)



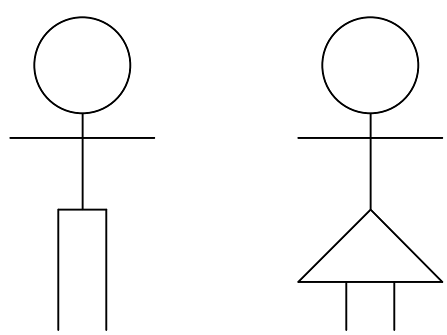
(e) What does this symbol mean?

(Variable in an equation:
X marks the spot.
Put your name here, etc.)



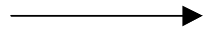
(f) What do these symbols mean?

(His and her bathrooms)



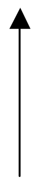
(g) Can symbols be used to express an idea or concept?

(Yes)

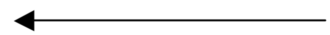
(h) What does this arrow mean? 

(An arrow could represent going right, a push to the right, or in general, something to the right.)

(i) What does this arrow mean?



(The arrow shows something upward, e.g., motion, force or direction.)

(j) What is the difference between the arrow in (h) and this arrow? 

(Two things: First, this arrow goes left, not right; and secondly, this arrow is larger.)

(k) What two properties of arrows seem to be illustrated by (h), (i) and (j)?

(Size and direction)

(l) Could an arrow indicate which way something moves?

(Yes)

(m) Could an arrow indicate how fast something moves?

(Yes)

(n) Could an arrow indicate the nature of force acting on an object?

(Yes)

(o) Summary: Can an arrow describe the size and direction of a physical quantity?

(Yes)

Topic 1: C-2 – Walking Vectors (Displacement)

Purpose: Experience one example of a vector by doing this activity.

Materials Needed: Orienteering compass, deck of 5 displacement cards, starting object

Preliminary: Teacher input
(a) How to use the orienteering compass
(b) Discuss the 5 displacement cards: 10 steps south, 10 steps east, 5 steps north, 5 steps west, 5 steps north
(c) Show how to walk consistently by placing black electrical tape every meter on the floor for 10 meters. (Students need to practice walking.)

Procedure:

(a) Students practice walking normal steps to become consistent. Try walking 10 steps in one direction and turn around and walk 10 steps in the other direction. Where should you end up?

(b) Go to a large open space (gym, outside, etc.) with your deck of cards and a starting object like a stake to mark your starting location.

(c) Shuffle your cards.

(d) Students begin at the chosen starting object and use their compass to walk the first card's displacement. From that point, walk the second card's displacement. Repeat for cards 3, 4 and 5 and write the order in which you walked in the grid below.

	Card 1	Card 2	Card 3	Card 4	Card 5	Distance	Displacement
Trial 1							
Trial 2							
Trial 3							

(e) What is the total distance walked in Trial 1? ______________________

(f) What is the displacement in Trial 1? ____________________________

(g) Shuffle your cards and repeat steps d, e, and f for a second and third trial.

Distance Trial 2 = __________________________

Displacement Trial 2 = ______________________

Distance Trial 3 = __________________________

Displacement Trial 3 = ______________________

Look at your distance walked and your displacement in each trial. What conclusion(s) can be drawn about vector addition?

Topic 1: C-2 – Walking Vectors (Displacement) Answer Sheet (f on separate page)

Trial 1	10 south	10 east	10 north	5 west	5 north	35	5 east
Trial 2	5 west	10 south	10 north	5 north	10 east	35	5 east
Trial 3	5 north	10 east	5 west	10 south	10 north	35	5 east
						Distance	Displacement

(e) 35

(f) 5 east

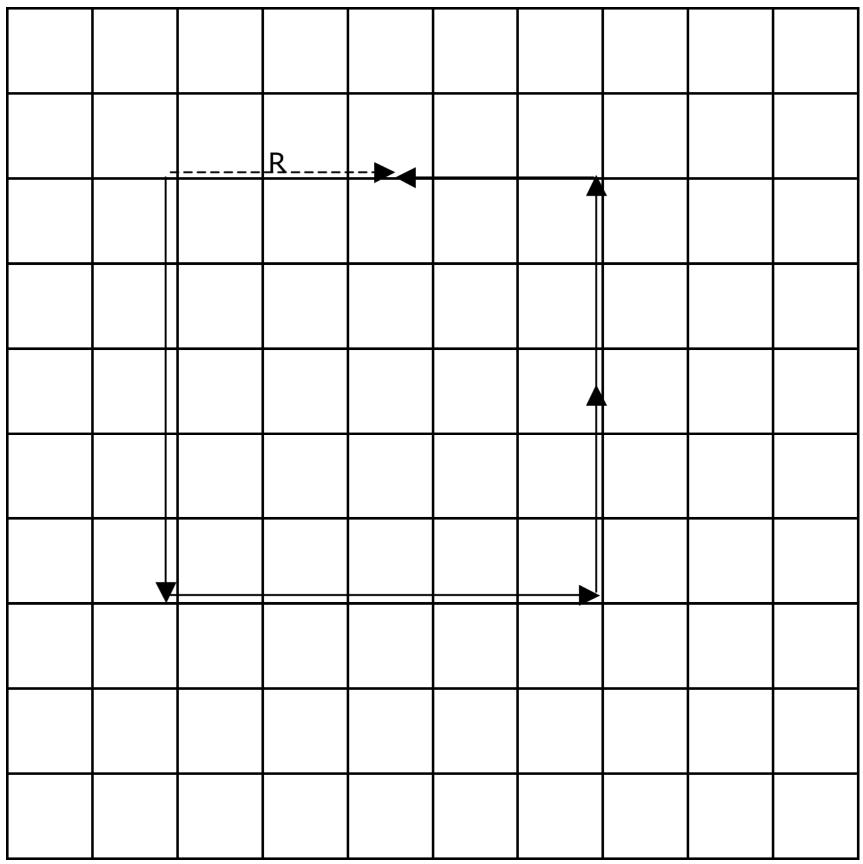
(g) Distance Trial 2: 35
Displacement Trial 2: 5 east
Distance Trial 3: 35
Displacement Trial 3: 5 east

(h) Conclusion: The order of vector addition does not matter and results in the same resultant, displacement.

Topic 1: (f) Walking Vectors (Displacement) Answer Sheet

One possible addition to obtain resultant displacement:

10 steps south, 10 steps east, 5 steps north, 5 steps north, 5 steps west



Topic 1: D – Vector Practice Worksheet

Purpose: To become familiar with the concept of a vector. Displacement vectors are one example and will be used to introduce the topic.

Theory: We will use the navigational coordinate system to define direction. This means that north is drawn up on a map or sheet of paper, south is down, east is to the right and west is to the left.

To describe how far, distance, in this exercise, one space on the evenly spaced grid paper will be 10 units of distance. For a vector, the length of the line segment indicates size and an arrowhead shows direction.

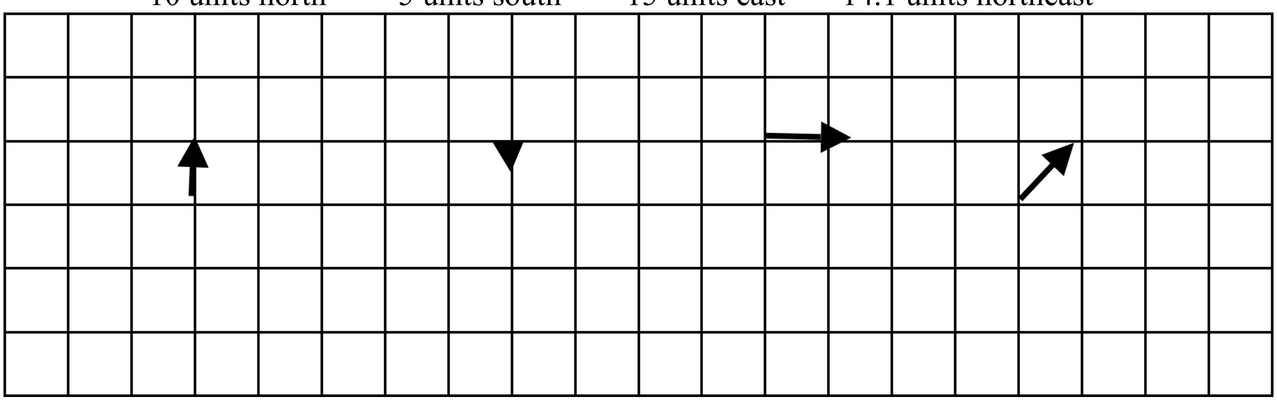
1. Vector Examples:

(a) 10 units north

(b) 5 units south

(c) 15 units east

(d) 14.1 units northeast



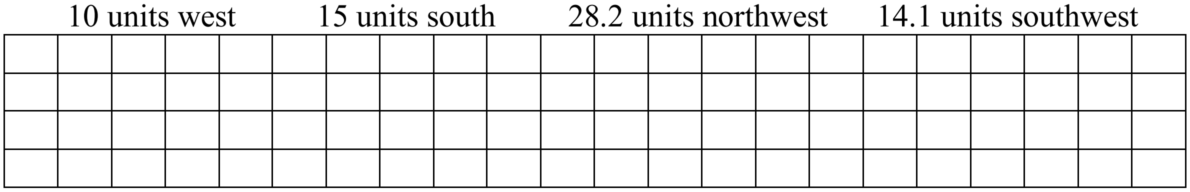
2. You draw these vectors:

(a) 10 units west

(b) 15 units south

(c) 28.2 units northwest

(d) 14.1 units southwest

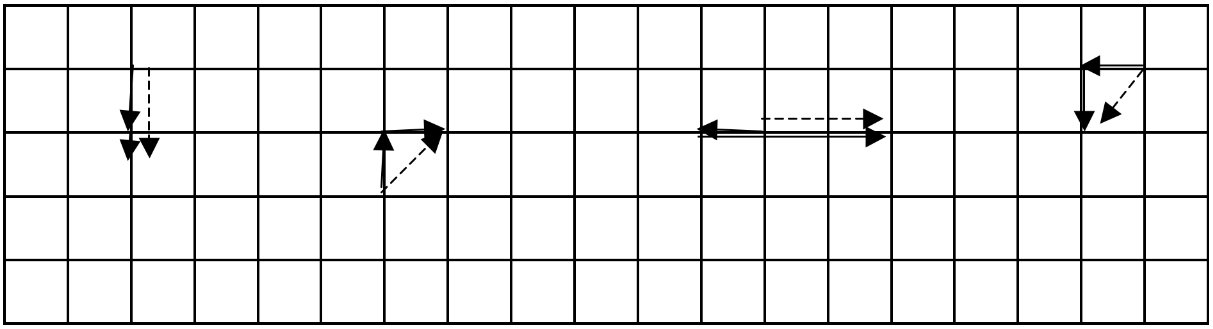


Adding Vectors

Theory: After drawing your first vector, start the second vector where you stopped the first vector (the arrowhead). The vector sum starts at the tail of the first vector and ends at the arrowhead of the second. This sum is called a resultant.

3. Examples: Vector Addition

(a)	(b)	(c)	(d)
Add 10 units south and 5 units south	Add 10 units north and 10 units east	Add 10 units west and 30 units east	Add 10 units west and 10 units south



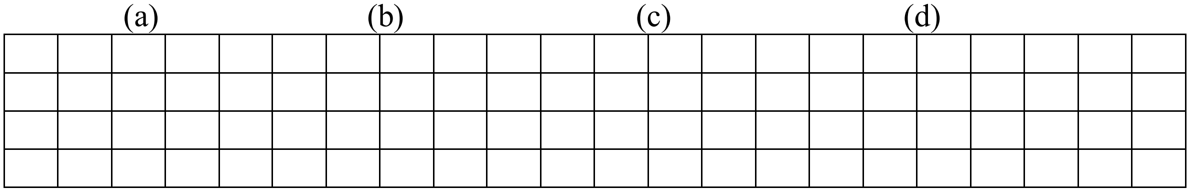
Answers:

Resultant = 15 units south   R = 14.1 units NE   R = 20 units east   R = 14.1 units SW

4. You add these vectors:

(a)	(b)	(c)	(d)
10 units north	20 units west	20 units east	20 units east
20 units south	20 units south	20 units east	40 units south

(a) (b) (c) (d)

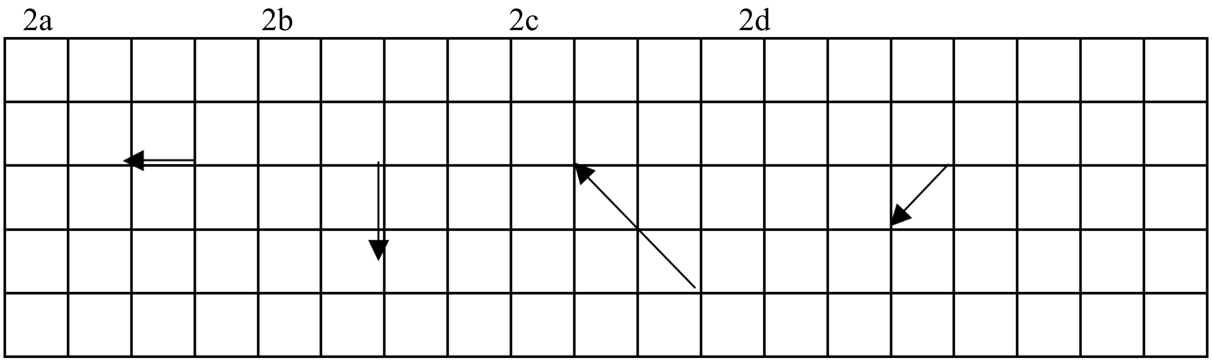


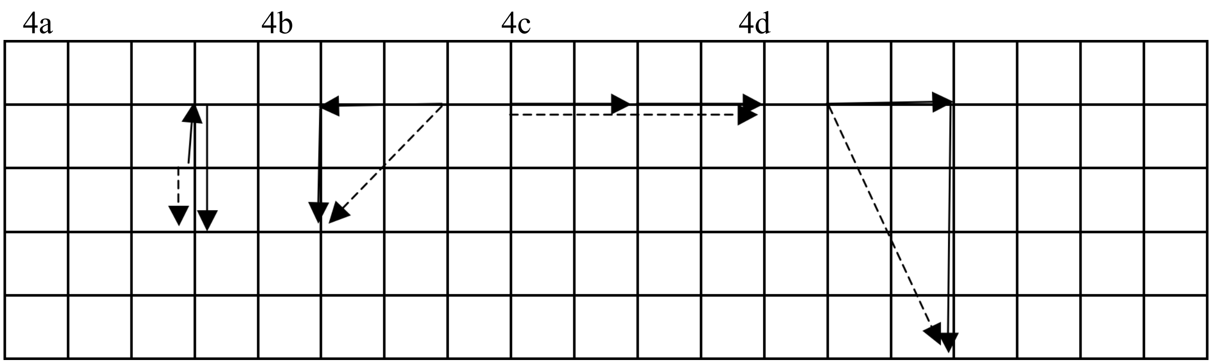
R =   R =   R =   R =

Question:

How can you obtain the resultant for 4d?

Topic 1: D – Vector Practice Worksheet Answer Sheet





R = 10 units south   R = 28.2 units southwest   R = 40 units east   R = 44.7 units southeast

Question:
Measure the resultant to see how many spaces long it is: About 44.7 units southeast

Topic 1: E-1 – Step Displacement Vector Demonstration

A very visual, inexpensive, quick and effective way to illustrate vectors (displacement for starters) is to begin by stepping off displacement vectors. Below is one possible presentation to a class including guided questions to help students with the understanding of displacement vectors. The teacher could modify this create a student activity or use as presented. I have found this demonstration to work well and it is just about the correct length.

1. Begin by lining up 10 or so objects (books, whatever) as location markers at 1 step spacing in front of the class. Call an object near the center the 0 step marker.

   0 0 0 0 0 0 0 0 0 0 0 0 0

2. Define going to the right as positive and left as negative (a number line).

3. Stand at 0 step and take 2 steps to the right (event 1).
   Ask: What distance did I travel? (2 steps)

4. From this location, take 2 steps to the left (event 2).
   Ask: What distance did I travel? (2 steps)

5. Ask: What is the same about events 1 and 2?
   (Both cover the same distance.)

6. Ask: What is different about events 1 and 2?
   (The direction: Event 1 went right and event 2 went left.)

7. Repeat from 0 step, but take 3 steps to the right (event 3).
   Ask: What distance did I travel? (3 steps)

8. From this location, take 3 steps to the left (event 4).
   Ask: What distance did I travel? (3 steps)

9. Ask: What is the same about events 3 and 4?
   (Both cover the same distance.)

10. Ask: What is different about events 3 and 4?
    (Direction)

11. Ask: What 2 physical properties about my stepping seem to describe what was done?
    (Distance and direction)

12. *Define* a displacement vector: An arrow (directed line segment) that has size (distance in this case, 2 and 3 steps) and direction (left and right in these cases).

13. Now start at location –1 step and go to location +2 steps (event 5).
    Ask: Will someone give me another event (6) that matches event 5? (Many possible answers, e.g., from –6 steps to –3 steps, from –2 steps to +1 step, from 2 steps to 5 steps and so forth)

14. Ask: What distance was covered in event 6? (3 steps) What displacement was covered in event 6? (+3 steps, to the right)

15. Now, start at location 4 steps and go to location 1 step (event 7).
    Ask: Will someone give me another event (8) that matches event 7? (Many possible answers, e.g., from 0 step to –3 steps, from –1 step to –4 steps, from 6 steps to 3 steps and so forth)

16. Ask: What distance was covered in event 7? (3 steps) What displacement was covered in event 7? (-3 steps, to the left)

17. Now, start at location 0 step and go 2 steps to the right. Next, take 2 steps at right angles to the number line toward the students.
    Ask: What total distance did I travel? (2 + 2 = 4 steps)
    Ask: What displacement occurred? (Less than 4 but greater than 2) Using math, 2.8 steps at 45 degrees to the number line. This is a 2-dimensional problem.

Vector Maze – Overview

1. Find your way through the maze to reach planet Zog.

2. The grid is on four squares per inch graph paper. Each square is one unit.

3. Count the number of units up, down, right and left (north, south, east, west).

4. Total all of the north-south units (vertical components). Up: 60, down: 81. Total: down 21 (-21).

5. Total all of the east-west units (horizontal components). Left: 24, right: 48. Total: 24.

6. Graphically add the vertical and horizontal components.

7. Draw the resultant.

8. Find the magnitude and direction of the resultant.

<u>Discussion Points</u>:

1. Distance and displacement: How many units were actually traveled to get from the point of origin to the point of destination?

2. When at planet Zog, how far are you from where you started?

3. Discuss the concept of components and resultants.

4. Would any other path through the maze have given similar results?

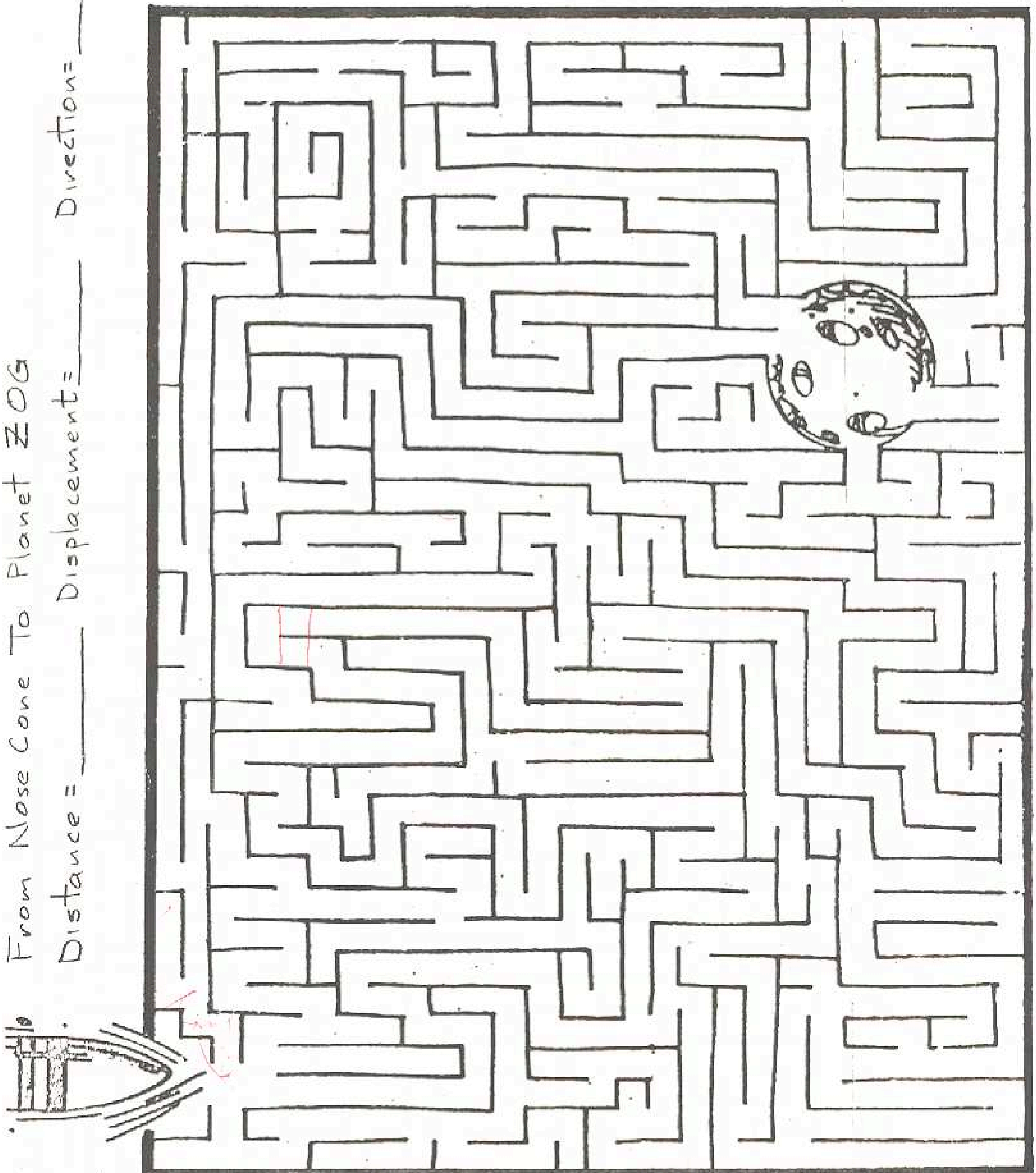
Vectors
Distance & Displacement

Name ____________________

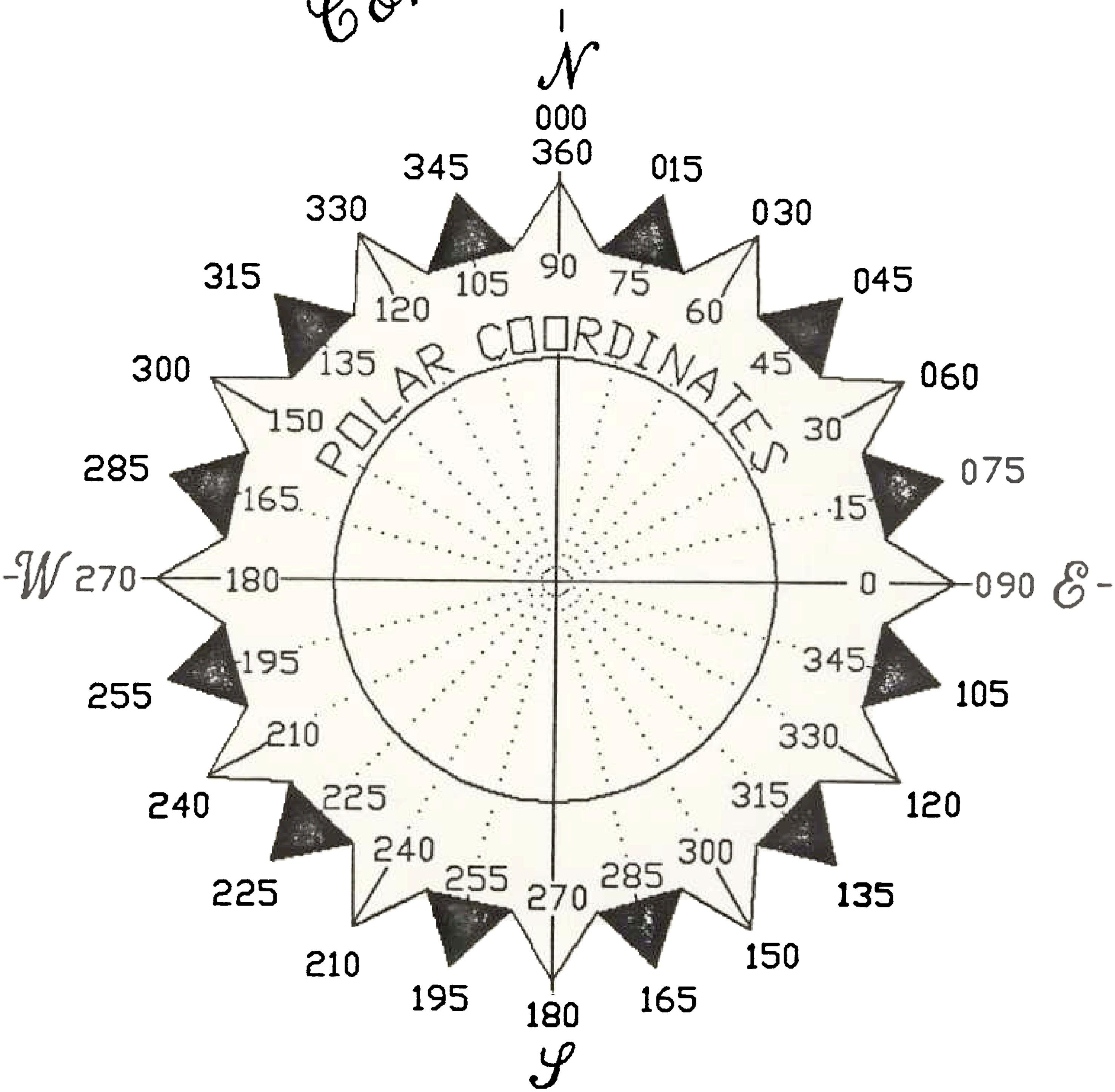
Date ____________ Hour ________

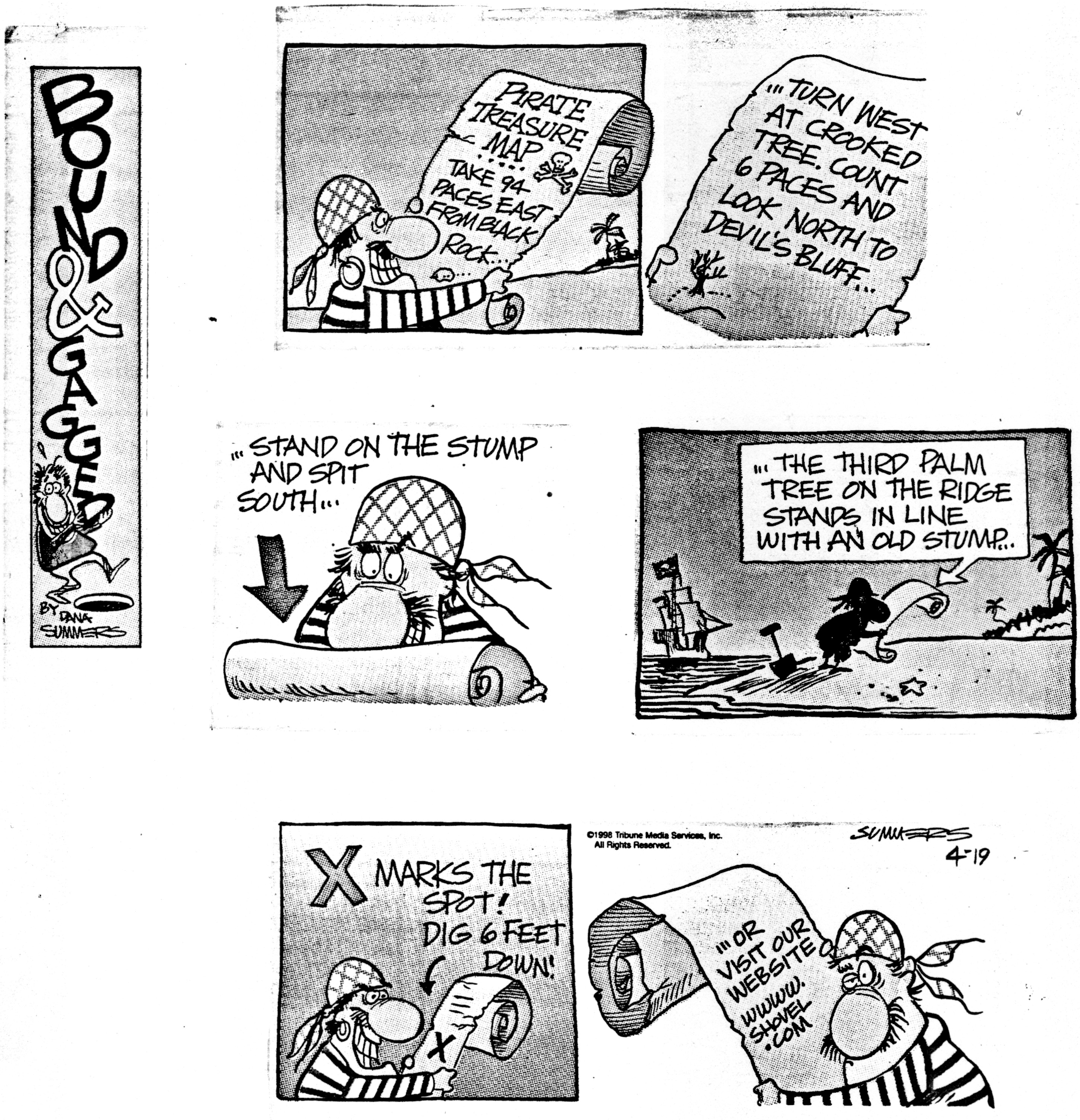
From Nose Cone To Planet ZOG

Distance = ________ Displacement = ________ Direction = ________



Polar Coordinates Compass Bearing Conversion Chart




BOUND & GAGGED
BY DANA SUMMERS
PIRATE TREASURE MAP
TAKE 94 PACES EAST FROM BLACK ROCK...
...TURN WEST AT CROOKED TREE. COUNT 6 PACES AND LOOK NORTH TO DEVIL'S BLUFF...
...STAND ON THE STUMP AND SPIT SOUTH...
...THE THIRD PALM TREE ON THE RIDGE STANDS IN LINE WITH AN OLD STUMP...
X MARKS THE SPOT! DIG 6 FEET DOWN!
X
...OR VISIT OUR WEBSITE WWWW. SHOVEL .COM
SUMMERS
4-19

Direction

A sailor at sea out of sight of land sits at the center of a circle whose circumference is the horizon. If he is standing on deck, eye level is about nine feet above sea level. At this height the diameter of his circle is only about seven miles. From the crow's nest, about seventy-five feet, the diameter is now about twenty miles. It is this circle, which defines our sailor's system of navigation.

For the thirteenth century Italian sailor, the frame of reference is not a point on a magnetic compass but more physical phenomenon; for north, the prevailing winds; for south, the midday sun; for east, the sunrise; for west, the sunset. Northern Europeans were the first to use the terms north, south, east and west to denote these directional properties. The Anglo-Saxon king Alfred the Great in the ninth century coined he terms northeast, northwest, southeast, southwest in order to add precision to the existing circular scale.

The Chinese, centuries before any western writings, were aware of the directional properties of a metal needle when touched by a lodestone. It is interesting to note that the Chinese refer to a south-pointing needle. Although apparently originating in early China, the magnetic compass, as a directional instrument, remained undeveloped by as late as the thirteenth century, at which time western technology surpassed its eastern counterpart.

It would take the navigating world another five hundred years to find the "North Magnetic Pole."

Topic 1: Vectors (b) – Velocity (Second Example)

Source: *Conceptual Physics* by Paul Hewitt and any junior-senior-level high school textbook

Types of Material: Textbooks, laboratory manual, demonstration, worksheet and activity

Building on: This is the second vector introduced to the new physics student to start seeing that vectors are present in many physical situations. Motion will be addressed for mastery in topic 2, kinematics. Also in topic 2, acceleration will be studied.

Leading to: Once vectors start to make sense and the student studies kinematics, the study of the cause of motion, dynamics, will be studied.

Links to Physics: Velocity vectors just illustrate a second example of a directed physical quantity. Again, worksheets and activities will help in the abstraction of a vector.

Links to Chemistry: Brownian motion, osmosis, diffusion rates, average kinetic energy of molecules, e motion in the atom

Links to Biology: Single cell, cilia, invertebrate systems, bone growth, and skeletal muscles relating to their motion

Materials:

Laboratory/Activities

(a) Hewitt – Conceptual Physics
Lab 2 – The Physics 500
Lab 3 – The Domino Effect
Lab 4 – Merrily We Roll Along
Lab 6 – Race Track

(Hewitt and Hsu's labs may best be done in topic 3 of this reference book.)

(b) Hsu – CPO Physics
Lab 1A – Time, Distance and Speed

(c) My Lab*

(d) Worksheets
Hewitt – Concept-Development Practice Book
2.1 – Motion

2.2 – Speed and Distance
2.3 – Vectors

Hsu*

Mine – Velocity Worksheet

(e) Demonstrations
1. Velocity Demonstration
2. Ball on Incline

(f) Websites and Videos
1. ESPN SportsFigures “Tracking Speed” Video Guide (Olympic Decathalon)
2. Moving Man Sim (Java)
3. Mechanical Universe Video Guide: “Falling Bodies”

(g) Good Stories – None*

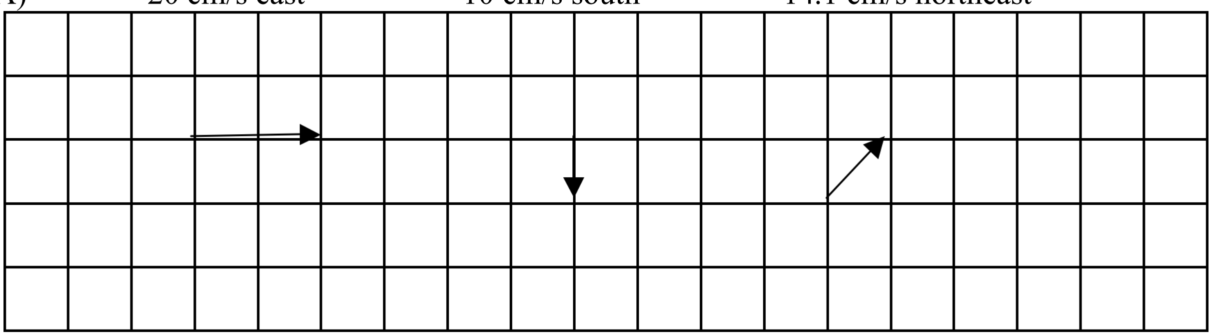
Topic 1: (b) D-1 – D Velocity Worksheet

Purpose: To work with and add velocity vectors.

Theory: As with displacement, velocity can be represented by a directed line segment, the vector. One space on the grid below will represent 10 cm/s. Direction is indicated by the navigational system.

Velocity Vector Examples:

(A) 20 cm/s east 10 cm/s south 14.1 cm/s northeast



You draw these vectors:

(B) 20 cm/s north 28.2 cm/s northwest 5 cm/s west

<u>Adding Velocity Vectors</u>:
Theory: Use the same vector addition rules established in the displacement worksheet.

(C) Add 10 cm/s north and 10 cm/s east Add 10 cm/s east and 30 cm/s west Add 10 cm/s south and 40 cm/s east

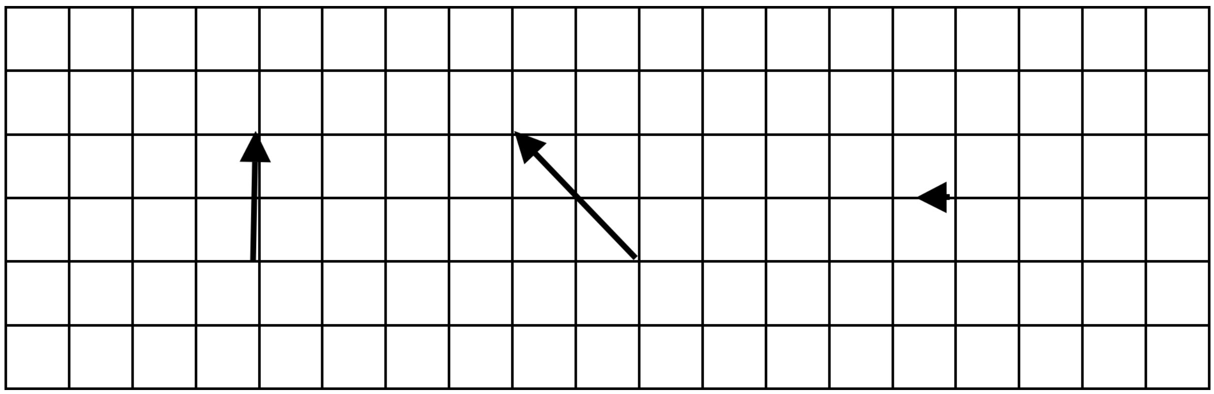
R = _____ R = _____ R = _______

<u>Question</u>:
What technique is used in finding the resultant velocity?

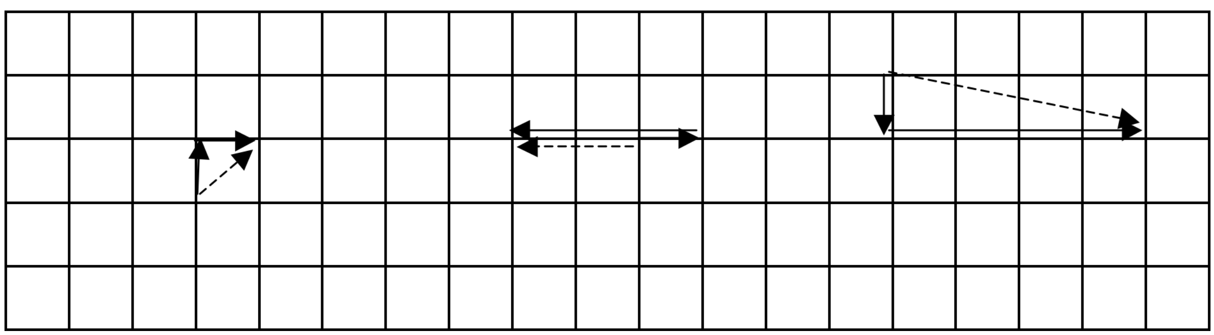
Topic 1: D – Velocity Exercises Answer Sheet:

D (b)

20 cm/s north 28.2 cm/s northwest 5 cm/s west



(c)



R = 14.1 cm/s northeast R = 20 cm/s west R = 41.2 cm/s southeast

Question:
Add the two or more vectors, draw the resultant and measure its length to compare it to the grid. Observe the direction it points and record. See (c) with "R" values.

E-1 – Velocity Demonstrations

(The below values are made-up measurements for purpose of illustration.)

(a) V = 1 m/2.5 s = 0.4 m/s

(b) V = 1 m/2.0 s = 0.5 m/s

(c) V = 0.9 m/1 s = 0.9 m/s

(d) R = 0.9 m/s

(e) V = 0.1 m/1 s = 0.1 m/s

(f) R = 0.1 m/s upstream

(g) R = 0.62 m/s

(h) Yes, add the two velocity vectors and measure the resultant.

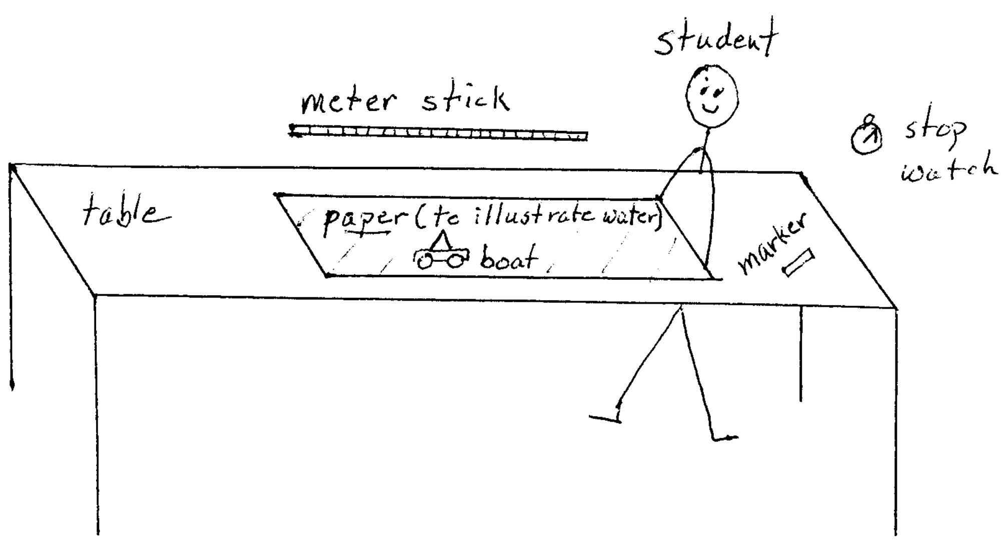
Topic 1: E-1 (a) – Velocity Demonstration

Purpose: To "see" velocity in action.

Theory: Relative motion will be seen and drawn on the "pretend" water using our "pretend" boat.

Materials: Very slow-moving electric or wind-up device (boat), about a 2-m-long newsprint paper works well (water), meter stick, stopwatch, large flat table (floor as backup), and a pen or marker

Setup:



Procedure:

(a) Find a student who can pull the 2 m paper at a slow constant rate (similar to the boat) across the table.

(b) Mark off 1 m on the "water." While pulling the paper, time the paper going 1 m. Divide 1 m by the time to find the "water" speed. V = d/t V =

(c) Time the "boat" to go 1m. Calculate its speed. V = d/t V =

(d) Aim the boat in the direction of the water and figure out the speed of the boat relative to the shore (fixed table). V = d/t V =

(e) Draw the two velocity vectors on the water using the marker. Draw the vector addition vector (resultant) as a dotted directed line segment on the water.

(f) Aim the boat opposite to the direction of the water and figure out the speed of the boat relative to the shore (fixed table). V = d/t V =

(g) Draw the two velocity vectors on the water using the marker. Draw the vector addition vector (resultant) as a dotted directed line segment on the water.

(h) Aim the boat across the water (90). Calculate the speed relative to the shore. V = d/t
V =

(i) Is there a way to find the relative speed other than what you did in (h)?

Topic 1: E-2 – Velocity Demonstration (Ball on Incline)

This demonstration should follow a presentation on vectors. The demonstration gives a simple visual display of constant motion (A) and accelerated (faster and faster) motion (B). The following items can be used for this demonstration.

1. Slow-moving electric car (or, slow-moving bowling ball)
2. 5-6 small marking objects (e.g., blocks of wood)
3. Meter stick
4. Stopwatch
5. Marble
6. Long, straight ramp for marble
7. Blank paper, pen and scissors and calculator

Procedure:

A)

1. On the flat floor, in the front of the class, start the slow car (or bowling ball) moving at one side of classroom toward the other.

2. Using a stopwatch, mark the location of your moving objects every 2 s for 5 or 6 times.

3. Measure the distance between each marker and divide by 2 s to calculate the average velocity between consecutive markers. Write the velocities in order on the chalkboard. (They should be showing a nearly constant trend—constant velocity.)

4. Draw and cut out arrows from paper to scale for each velocity arrow "vector" and place them on the original track to "see" the velocity vectors.

B)

1. Set up a long straight ramp at a small angle in front of the class.

2. From rest, roll the marble and time its motion every 2 s as it goes down the ramp. Mark the location every 2 s with a marker.

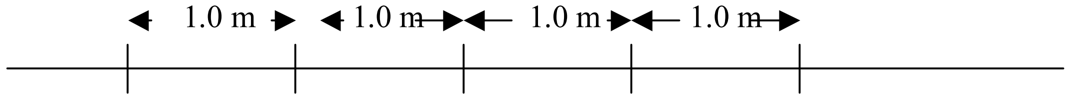
3. Measure the distance between consecutive markers and divide by 2 s to calculate the average speed between consecutive markers. Write these velocities in order on the chalkboard. They should show a trend of getting larger or accelerating.

4. Draw and cut out to scale from paper each velocity arrow "vector" and place them on the ramp to "see" the velocity vectors.

Topic 1 (b): E-2 – Velocity Demonstration Answer Sheet

(Sample Data – Everyone's results will only follow same trend.)

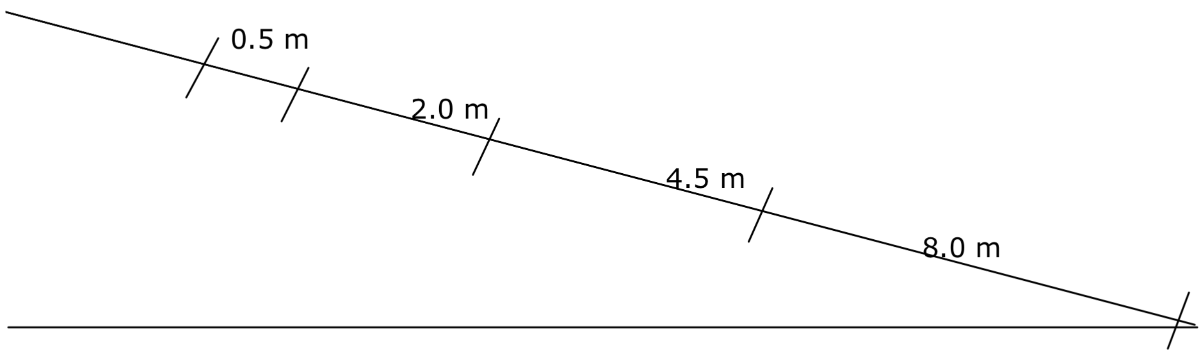
A)



V1 = 1 m/2 s = ½ m/s V2 = 1 m/2 s = ½ m/s V3 = 1 m/2 s = ½ m/s V4 = 1 m/2 s = ½ m/s

So, V1 = V2 = V3 = V4 m/s
This trend shows constant velocity.

B)



V1 = 0.5 m/2 s = 0.25 m/s

V2 = 2.0 m/2 s = 1.0 m/s

V3 = 4.5 m/2 s = 2.25 m/s

V4 = 8.0 m//2 s = 4.0 m/s

(These are only sample data values, however, the trend shows the object going faster and faster or accelerating.)

Topic 1: Vectors – (c) Force (Third Example)

Source:	*Conceptual Physics* and CPO physics textbooks and laboratory books
Types of Material:	Textbooks, laboratory manuals, worksheets and activities
Building on:	The force vector is the third example to complete the introduction to vectors. A similar worksheet and activity will carry through the learning process and can be drawn on throughout the entire class.
Leading to:	With the introduction to force as a vector, topic 3 on dynamics will give the student a head start to the significance of force in our world. Again, mastery is scheduled for topic 3.
Links to Physics:	Force plays a significant role in mechanics, thermodynamics, vibration and wave motion, electricity and magnetism, light and optics, and modern physics. Force causes changes in motion of cars, electrons, molecules and so on.
Links to Chemistry:	The Coulomb force law, Van der Waal force and bonding forces
Links to Biology:	Physical therapy involves applying forces to muscles and joints at the proper tension/compression as well as direction (VECTORS). Forces in animals and humans occur in pairs by muscles to create contraction and extension. To understand molecular motion as in diffusion, an understanding of force is needed.

Materials:

(a) Hewitt – *Conceptual Physics*
Lab 10 – 24-Hour Towing Service

(Hewitt and Hsu's labs should be considered being done in topic 4 of this reference book since master is not the goal at this time.)

(b) Hsu – CPO Physics
Lab 5A – Equilibrium
Lab 5B – Friction

(c) My Labs
C-1: Force Vectors

(d) Worksheets
Hewitt – Concept-Development Practice Book
4-2 - Statics
4-3 - Force and Velocity Vectors
5-3 - Force Vector Components
5-4 - Equilibrium on an Inclined Plane

Hsu*

My Lab
Force Practice Worksheet

(e) Demonstrations
E-1: Vector Components

(f) Websites and Videos
(Presented in topic 4 of this reference book)

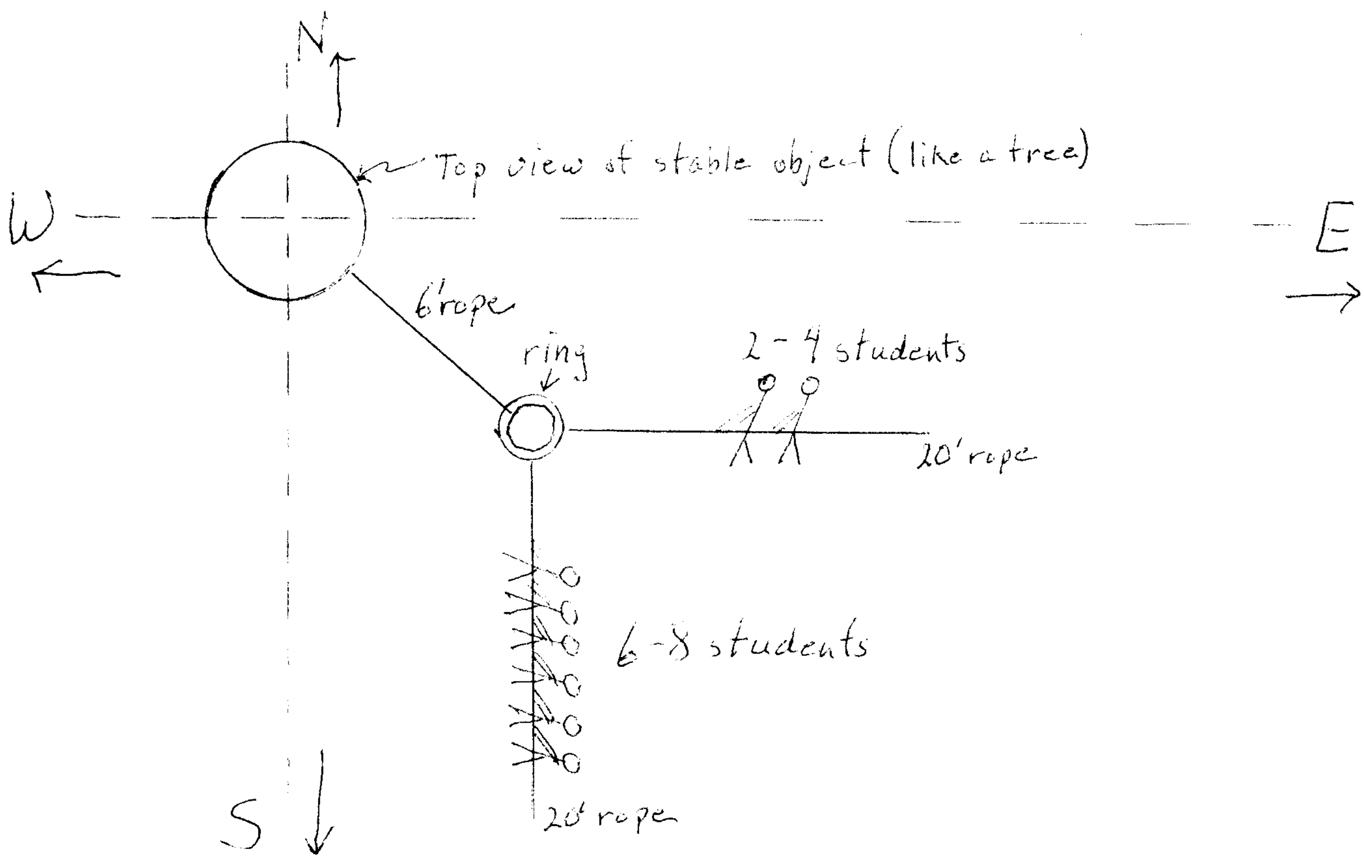
(g) Good Stories
1. The Wrath of Newton
2. Newton's Two Birthdays

(h) Vector Follow-Up Quiz/Test (1)
Follow-Up Quiz/Test Answer Sheet (2)

Topic 1: C-1 – Force Vector Activity

Activity: Force Vectors: (Feel the force. See the force.)

Setup: Top view of a stable object (like a tree)



Theory: This activity will show direction and relative size of a resultant formed from simultaneously applying two forces to a metal ring.

Procedure:

1. Tie a rope around a tree or other immoveable object and the other end of the rope to a metal ring. The rope between the tree and ring should be around 6 ft. long. Tie two additional ropes about 20 ft. long to the ring.

2. Have 2-4 students pull east on the rope on command.

3. Have 6-8 students pull south on the rope on command. (90 degrees to pull east)
4. Announce, 3, 2, 1 PULL. Observe the resultant direction of the rope attached to the tree. (Does the rope attached to the tree swing closer to east or south?)

5. On separate paper, sketch the addition of the two applied forces showing the larger force (6-8) with a longer line and the smaller force (2-4) with a smaller line. Recall that vectors are added head to tail. Draw the resultant from the tail of the first force vector to the end of the second force vector.

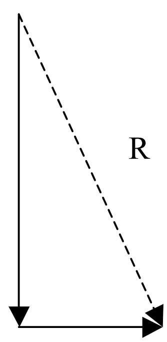
6. How big is the resultant force vector in comparison to the two forces that created the resultant? Why is this so? Compare the direction of the resultant to the two original applied two forces.

Repeat steps 2-6 but after switching positions of the two teams of students. (2-4 south and 6-8 east)

Topic 1: C-1 – Force Vector Activity Answer Sheet

4. The 6-ft. rope will swing closer to the south. (The 6-8 students will likely pull harder.)

5.



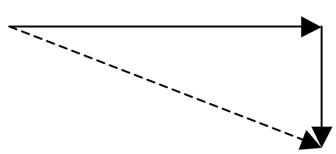
6. The resultant force (dashed line) is larger than either the south or east force because it is the vector sum of two force that result in a larger force due to their direction.

   The resultant force direction is closer to the south direction since the south force was larger.

7.

   4.) East

   5.)



   6.) Same as 6 above: East

Topic 1: D-1 – Force Practice Worksheet

Purpose: To become familiar with the concept of a vector, force vectors will be used to illustrate this point.

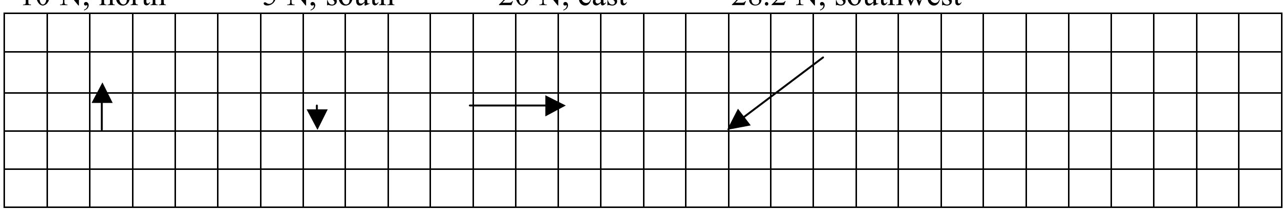
Theory: We will use the navigational coordinate system to define direction. This means north is drawn up on a map or sheet of paper, south is down, east is to the right and west is to the left.

To describe the size of a force, one space on the grid below will be 10 units of force. For a vector, the length of a drawn line segment indicates size and the arrowhead shows direction. As you will soon learn, the standard metric unit of force is the "Newton" (N); thus, 10 units of force is 10 N.

Force Examples:

(a)

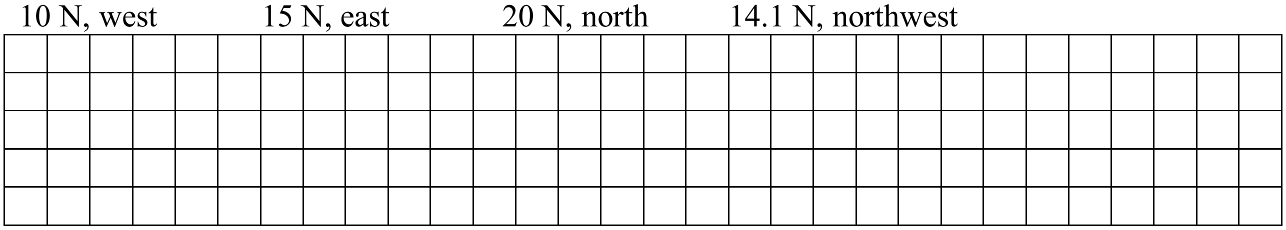
10 N, north   5 N, south   20 N, east   28.2 N, southwest



You draw these vectors:

(b)

10 N, west   15 N, east   20 N, north   14.1 N, northwest



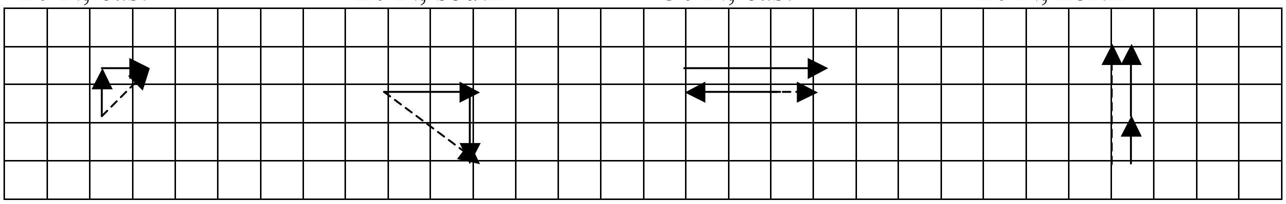
Adding Vectors:

Theory: After drawing your first vector, start the second vector where you stopped the first vector (the arrowhead). The vector sum starts at the tail of the first vector and ends at the arrowhead of the second. This sum is called a resultant. Measure the length of the resultant to obtain its size and see what direction it points to determine the resultant's direction.

Examples: Vector Addition of Forces

(c)

Add 10 N, north and 10 N, east | Add 20 N, east and 20 N, south | Add 20 N, west and 30 N, east | Add 10 N, north and 20 N, north



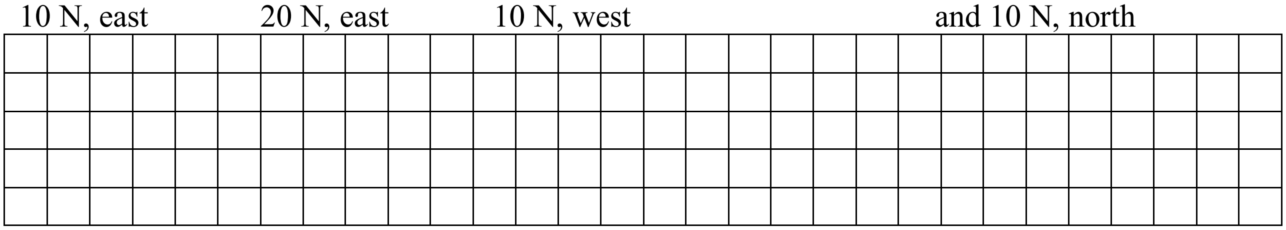
Answers:

R = 14.1 N, northeast | R = 28.2 N, southeast | R = 10 N, east | R = 30 N, north

You add these force vectors:

(d)

20 N, south and 10 N, east | 10 N, west and 20 N, east | 10 N, east and 20 N, south and 10 N, west | 10 N, north and 20 N, east and 10 N, north

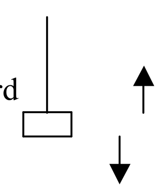


Answers:

R = 24.2 N, southeast | R = 10 N, east | R = 20 N, south | R = 28.2 N, northeast

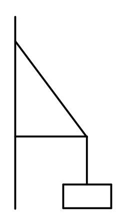
(e) If an object is at rest, all the forces acting on the object must total zero. For example, if an object hangs from a string, gravity downward is balanced by the string pulling upward. See the drawing.

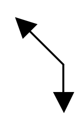
Pull of string upward



Gravity on object (weight)

You try:





Weight hanging from structure

Add the missing force to this force drawing.

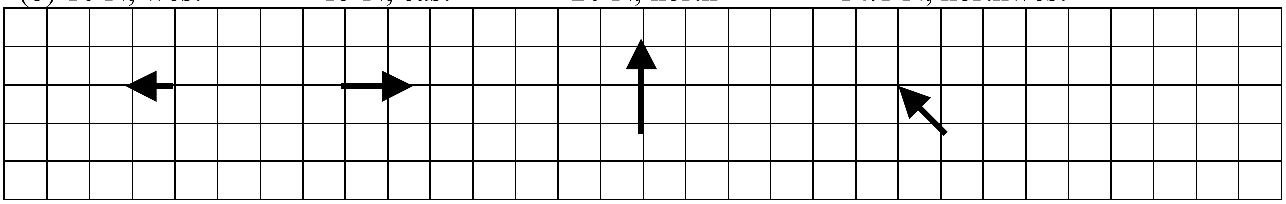
Additional Problems:

1. John pulls north on a wagon with 60 N, but Mary pulls south on the same wagon with 80 N. What is the resultant force?

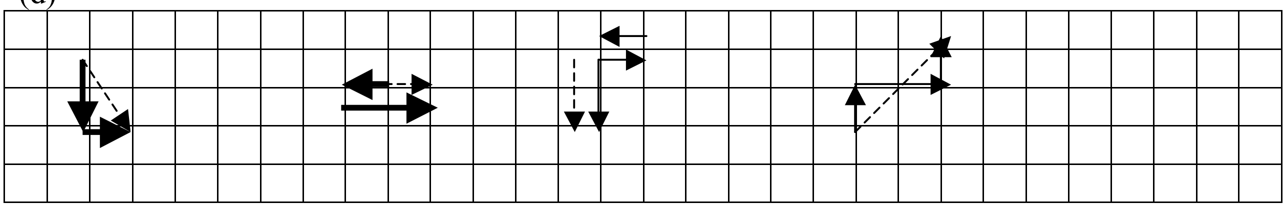
2. Frank the bird is flying with a north, 10 N-propelling force. The wind pushes on Frank at 20 N from the east. What is the resultant force?

Topic 1: D-1 – Force Exercises Answer Sheet

(b) 10 N, west 15 N, east 20 N, north 14.1 N, northwest

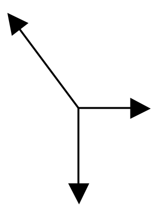


(d)

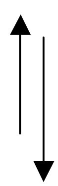


R = 24.2 southeast R = 10 east R = 20 south R = 28.2 northeast

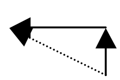
(e)



1. 20 N, south

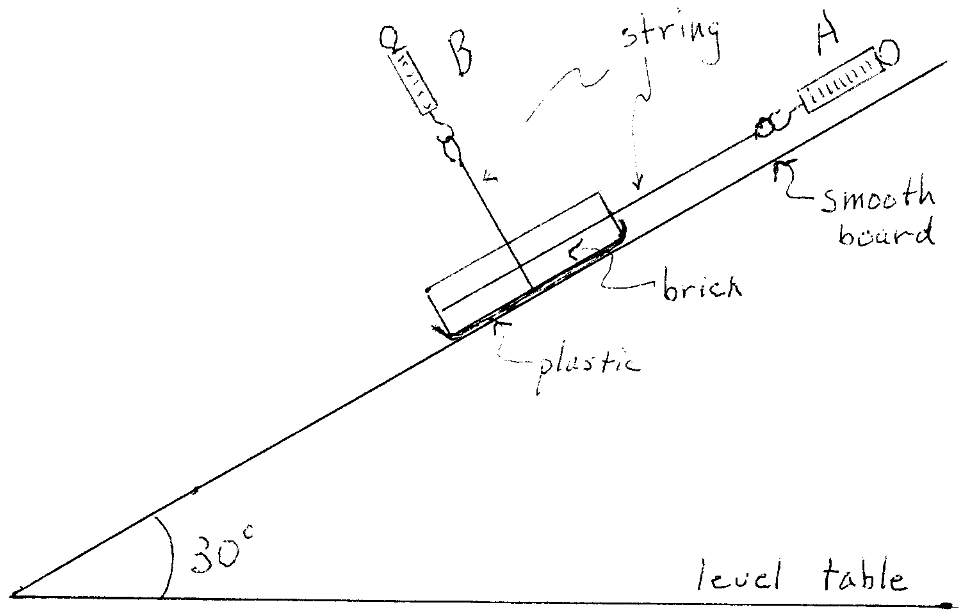


2. 24.2 N, northwest



Topic 1(c): E-1 – Demonstration: Force Components (or, parts of a whole)

Setup: (sketch)



Theory: One force vector can be made up from two or more forces (or, two forces can produce the same result as one force).

Procedure:

1. Secure a 2- to 3-foot smooth board and arrange it on a level table to form a 30-degree angle to form a ramp. Lock it in place.

2. Obtain a standard brick.

3. Tie a string around the middle of the brick leaving one end of the string about one-foot long and tie a loop at the end of this string. (See sketch.)

4. Repeat procedure 3 but tie the string in the middle between the ends of the brick. (See sketch.)

5. Brick/Board preparation:
   Cut 2-3 pieces from a thick plastic garbage bag slightly larger than the bottom of the brick. Duct tape these sheets to the bottom of the brick covering the two strings and keeping the duct tape on the sides of the brick and not on the bottom. Talcum powder the board and the plastic to obtain a low friction surface between the brick and board.

6. Attach a 20 N spring scale (A) to the string loop that is pulled parallel to the board. Have a student pull just hard enough to keep the brick from going up or down the incline. Record the force. F = ___________________N (force parallel)

7. How does the size of this force compare to the size of the force pulling the brick down (parallel to) the incline? Could you consider these two forces down the ramp and up the ramp, balanced forces?

8. Attach a 20 N spring scale (B) to the loop that is around the middle. Have a second student pull upward, perpendicular to the incline, until the brick just leaves the board. Hold it and record this force. F = ____________________N (force perpendicular)

9. How does the size of this force compare to the size of the force pushing the brick into the incline? Does the force into (perpendicular) the ramp balance the pull away from the ramp to create balanced forces?

10. Weigh the brick while it is hanging vertical. Weight = ______________________N

11. On separate paper, draw an incline from a horizontal at 30 degrees. Put a dot slightly above the incline to represent the brick. Draw a force vector to scale (example: let 1 cm = 2 N) starting at the dot and parallel to the ramp to match the force in step 6 (F parallel). Draw a second force to scale starting at the head of F parallel that is perpendicular to the ramp and F parallel at a size that matches step 8.

12. Draw the resultant between the tail of F parallel and the head of F perpendicular. Measure the size to scale of this resultant. R = ________________________N. Compare the size of the resultant to the weight of the brick.

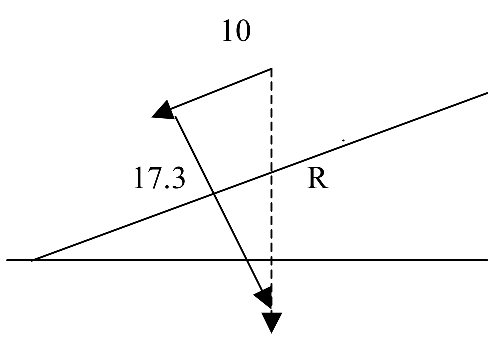
13. Can you consider the F parallel and F perpendicular to be two parts of the weight? Could we call these parts that combine to make the weight vector as force components?

14. What would happen if the ramp were removed when F parallel and F perpendicular were acting? Try it!

Topic 1(c): E-1 – Demonstration: Force Components Answer Sheet

(Below is sample data if the brick weighs 20 N.)

6. F = 10 N
7. Same, 10 N = 10 N

   Yes, they are balance forces.
8. F = 17.3 N
9. Same, yes, the force into and away from the incline are equal or balanced.
10. W = 20 N
11. 

12. R = 20 N; W = 20 N; the resultant of F parallel and F perpendicular equals the weight.
13. Yes, F parallel and F perpendicular are two parts that make up the weight. The two parts are force components.
14. Since the brick feels no net force, all balanced, the brick stays put (does not move).

Topic 1: Vector Follow-Up Quiz/Test

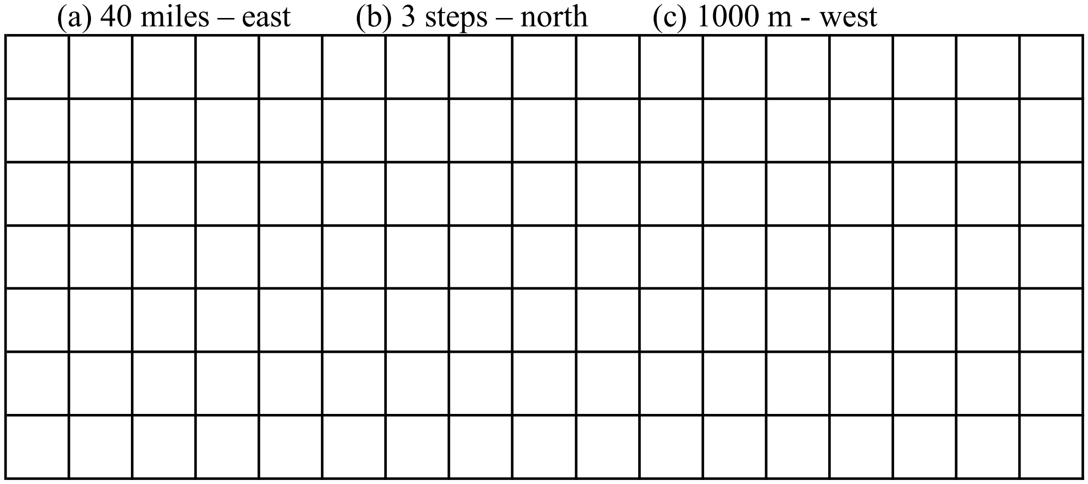
(Quiz about Vectors, Displacement, Velocity and Force)

1. Write a definition of a vector.

2. What three vectors have been worked with in this introduction to vectors?

3. Draw displacement vectors for the following three displacement vectors stating the scale you have chosen.

   (a) 40 miles – east (b) 3 steps – north (c) 1000 m - west



Scale:

(a) Let _______ spaces = ________ miles. (b) Let ________ spaces = _______ steps.

(c) Let _______ spaces = _______ m.

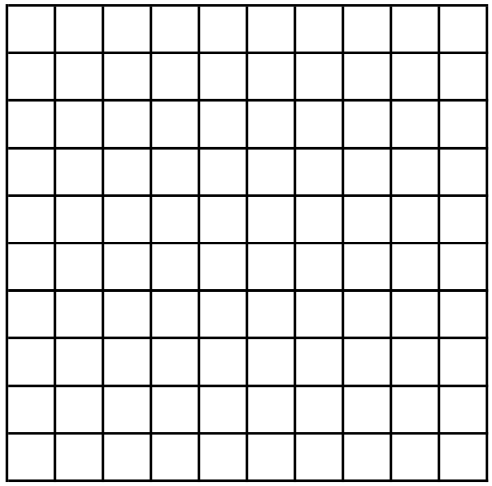
4. Draw a vector to represent a Corvette going east at 140 mi/hr.

Scale: Let __________ mi/hr = _________ spaces.

A raindrop falls feeling a force of gravity of 0.02 N but feels air resistance at 0.005 N. Show and state the total (net) force on the raindrop.

Scale: Let _______ N = _______spaces.

5. Add forces of 50 N east to 30 N south using vectors.



Scale: Let ________ N = _______ spaces.

Topic 1: Vector Follow-Up Quiz/Test Answer Sheet

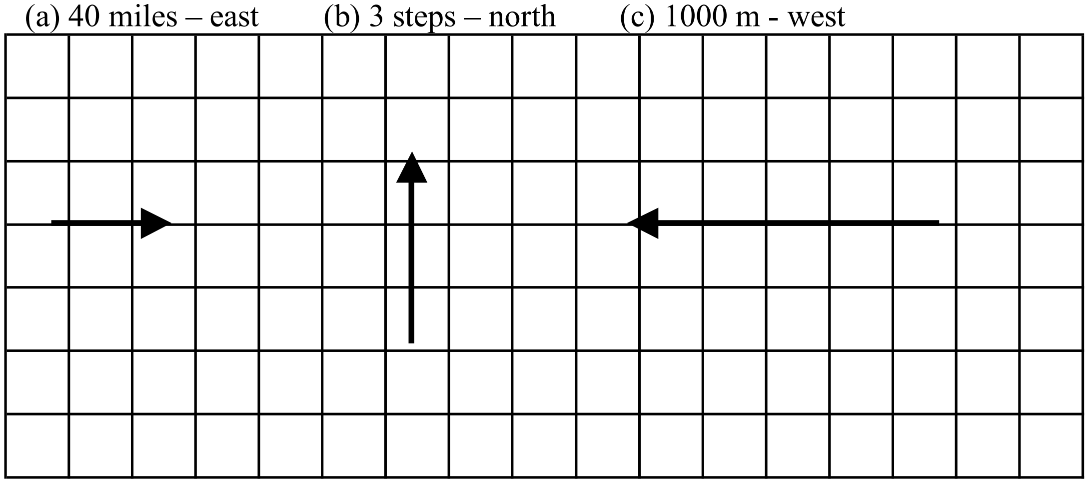
(Quiz about Vectors, Displacement, Velocity and Force)

1. Write a definition of a vector.
   A vector is a symbol (arrow) that represents a physical quantity that has a size (magnitude) and a direction.

2. What three vectors have been worked with in this introduction to vectors?
   Displacement, velocity and force

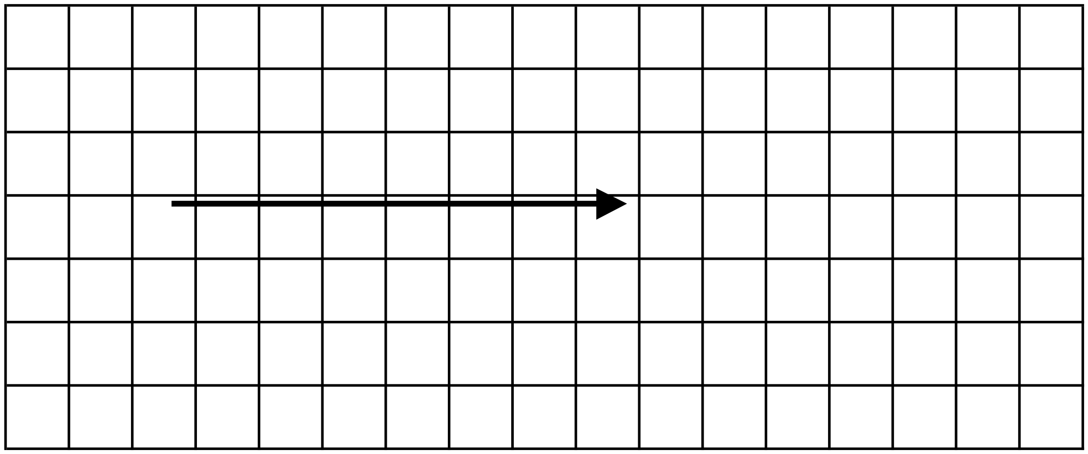
3. Draw displacement vectors for the following three displacement vectors stating the scale you have chosen.

   (a) 40 miles – east (b) 3 steps – north (c) 1000 m - west



Scale: (a) Let 1 space = 20 miles. (b) Let 1 space = 1 step. (c) Let 1 space = 200 m.

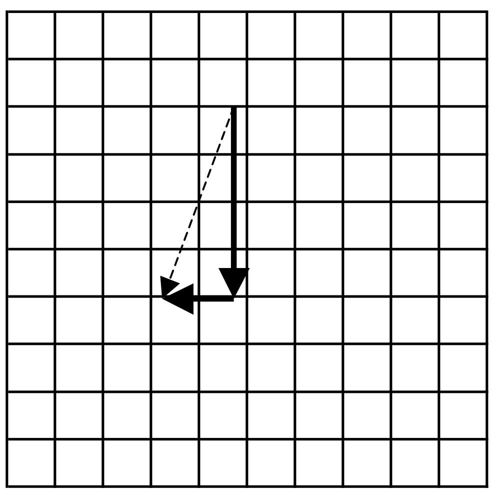
4. Draw a vector to represent a Corvette going east at 140 mi/hr.



Scale: Let <u>20</u> mi/hr = <u>1</u> space.

A raindrop falls feeling a force of gravity of 0.02 N but feels air resistance at 0.005 N.

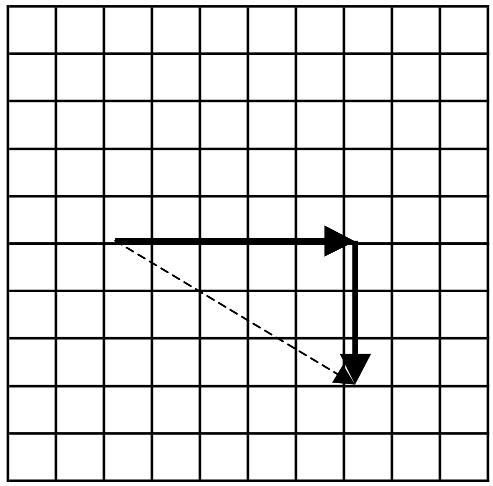
Show and state the total (net) force on the raindrop.



Scale: Let <u>0.005</u> N = <u>1</u> space.

Resultant = the dotted arrow on the drawing; larger than .02 but smaller than
0.02 N + 0.005 N; measure the dotted line (about 0.0205 N) going opposite the wind.

5. Add forces of 50 N east to 30 N south using vectors.



Scale: Let <u>10</u> N = <u>1</u> space.

Resultant = about 59 N directed down to the right (avoiding math at this time)