SCIENCE 10 HONOURS **VECTORS**

Scalar quantities express only magnitude:

Vector quantities express both magnitude and direction:

Distance, d = 10 km displacement, $\vec{d}$ = 5 km [E]

Vector quantities are represented by arrows, called vectors, in vector diagrams. The length of the arrow represents magnitude of the vector in the direction in which the arrow is pointing.

It is possible to use your math skills to solve these problems. You will have to use both Pythagoras and trigonometry.
Start by making a rough sketch which includes the information from the problem. Finally, use the math!

1. What is the total displacement of a trip of 50 km[W] followed by a trip of 100 km[30° E of N]?

2. What is the total displacement of a trip of 100 km[30° E of N] followed by a trip of 50 km[W]?

How does the answer of #1 compare to the answer of #2? Compare the questions. (Do you get the same answer if you add the vectors in reverse order?)

3. What is the total displacement of a trip to the store by Mike who goes 2 blocks[N], 3 blocks[E], 1 block[S], 5 blocks[W], 4 blocks[S], and then 2 blocks[E]?

Moving Inside A Moving Object Problems
A person in a moving object has two possible velocities: velocity relative to the moving object, and velocity relative to the ground.

A train moves at 50 km/h[N]. Jill is seated on the train and Mike is walking 5 km/h[N] towards her. Andrew is walking 7 km/h[S] towards Jill.
What is Mike's velocity relative to the train and to the ground?

What is Andrew's velocity relative to the train and the ground?

4. A baseball pitcher is warming up on an airplane on the way to a game. The plane is flying at 400 km/h[W] and the pitcher can throw the ball at 150 km/h. What is the velocity of the ball relative to the ground, if the pitcher throws the ball:
   a. towards the front of the plane?

   b. towards the back of the plane?

5. A jet plane traveling horizontally at 1200 km/h[E] fires a rocket forwards at 1100 km/h relative to itself. What is the velocity of the rocket relative to the ground?

6. A bowler is practicing his game on a railway flatcar traveling at 50 km/h[N]. If the velocity of the ball is 60 km/h[S] relative to the flatcar, what is its velocity relative to the ground?

7. A boat is traveling upstream at 5 km/h relative to the shore. If there is a current in the river of 7 km/h, how fast is the boat moving relative to the water?

River-Crossing Problems

Phil jumps into a river and swims for the opposite shore. In still water Phil can swim 4 km/h[N]. There is a current in the river pushing Phil downstream at 3 km/h[E]. As a result, he does not actually go north, but moves at an angle to the bank of the river. Find Phil's velocity.

8. A swimmer jumps into a river and swims straight for the other side at 3 km/h[N]. There is a current in the river of 4 km/h[W]. What is the swimmer's velocity?

9. A conductor in a train traveling at 12.0 km/h[N] walks across the aisle at 5.0 km/h[E] to punch a ticket. What is his velocity relative to the ground?

10. A small plane with a top speed of 100.0 km/h in still air is flown straight north. Unknown to the pilot, a 50.0 km/h wind is blowing to the west. What is the plane's velocity relative to the ground?

Airplane Navigation Problems

Solving these problems are just like river problems. Some helpful symbols: (pilots use them)

Symbol	Velocity vector	Speed	Direction
$\underset{v_a}{\rightarrow}$	plane's velocity relative to air	air speed	heading
$\underset{v_w}{\rightarrow}$	wind velocity (velocity of air relative to ground)	wind speed	wind direction
$\underset{v_g}{\rightarrow}$	plane's velocity relative to ground	ground speed	track

An airplane is heading east with an air speed of 120 km/h. A 40 km/h wind is blowing towards the south. Calculate the ground speed and the track for the plane's trip.

A pilot wants to fly west. The airplane has an air speed of 100 km/h. There is a 10 km/h wind blowing north. Calculate pilot's proper heading and ground speed.

11. A balloon pilot wants to travel north. The balloon can move at 26 km/h in still air. There is a wind of 10 km/h[E].
    a. What is the heading? (That is, which way should the pilot point the balloon?)

    b. How fast will the balloon travel relative to the ground?

12. An airplane pilot wants to fly east. The plane has an air speed of 500 km/h. A wind is blowing at 50.0 km/h[N]. Calculate:
    a. the proper heading

    b. the ground speed

Velocity Changes and Acceleration Vectors

Previously we defined acceleration as: $a = \frac{\Delta v}{\Delta t}$ where $\Delta v = v_2 - v_1$

Now that we know about vectors: $\vec{a} = \frac{\vec{\Delta v}}{\Delta t}$ where $\vec{\Delta v} = \vec{v}_2 - \vec{v}_1$

What is the acceleration of a ball that is thrown up into the air at a velocity of 20 m/s[up] and comes back 4.0 s later, with a velocity of 20 m/s[down]?

13. A train slows down from 50 m/s[E] to 34 m/s[E] in 4.0 s. What is its acceleration?

14. A car changes velocity from 25 m/s[E] to 40 m/s[W] in 10 s. What is its acceleration?

15. A ball is rolled up a ramp and has an initial velocity of 5.0 m/s[up]. 4.0 s later, it has a velocity down the ramp of 3.0 m/s[down].
    a. What is its accleration?

    b. At what moment during its trip was the ball stationary?

Lots of Practice on Vectors: Please answers these on a separate piece of paper

1. A plane flying a triangular pattern flies first 150 km[N], then 400 km[E].
    a. What is its total displacement after these two legs?
    b. What third displacement would complete the trip back to the starting point?

2. A boat sails 120 km[60° N of E], then 60 km[W]. What is its displacement?

3. A man inside a plane flying at 400 km/h[W] fires a gun eastwards. The muzzle velocity of the gun is 450 km/h. What is the velocity of the gun relative to the ground?

4. A street car accelerates from rest at 2.5 m/s^2[W]. A woman inside the street car is walking at 5.0 m/s[E] relative to the street car. What is her velocity relative to the ground at:
    a. 0 s b. 1 s c. 2 s d. 3 s e. 4 s

5. A man is walking inside a railway boxcar at 3 m/s[N] relative to the boxcar. The boxcar is rolling along a ferryboat at 5 m/s[S] relative to the ferryboat. The ferryboat is heading north at 4 m/s. What is the velocity of the man relative to: a. the ferryboat b. the ground

6. A boy and a girl both swim at 3.0 m/s. They jump into a river 1.0 km across, with a current of 2.0 m/s[E].
    a. The boy faces due north at all times. What is his velocity relative to the ground?
    b. The girl swims straight across. What is her velocity relative to the ground?

7. A motorboat is headed [30° N of E] with its engine set to move the boat at 30 km/h in still water. There is a current of 15 km/h[S]. What is the velocity of the boat?

8. A boy in a car moving at 10 km/h[N] wants to throw a ball to a girl standing on the right-hand side of the road. He is able to throw the ball at 20 km/h. He wants the ball to go straight east, directly to her.
    a. Which way should he throw the ball in order to do this?
    b. How fast will the ball travel to reach her?

9. A pilot want to fly north. The plane has an air speed of 350 km/h. There is a 25 km/h wind blowing to the west. a. What is the plane's ground speed? b. What is its heading?

10. A ball rolls up a hill, starting at 10 m/s[up] and accelerating at –3m/s^2[up]. What is the velocity after:
    a. 1 s b. 3 s c. 4 s

1. a. *427 km[69° E of N]* b. *427 km[21° S of W]* 2. *104 km[N]* 3. *50 km/h[E]* 4. a. *5.0 m/s[E]* b. *2.5 m/s[E]* c. *0 m/s* d. *2.5 m/s[W]* e. *5.0 m/s[W]* 5a. *2 m/s[S]* b. *2 m/s[N]* 6a. 3.6 m/s[34° E of N] b. *2.2 m/s[N]* 7. *26 km/h [E]* 8a. *[30° S of E]* b. *17 km/h* 9a. *349 km/h* b. *[4.1° E of N]* 10a. *7 m/s[up]* b. *1 m/s[up]* c. *–2 m/s[up] or 2 m/s[down]*