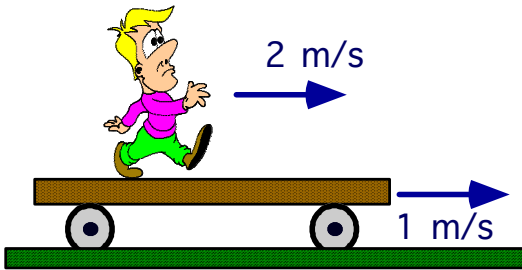


Unit 2: Kinematics in 2D

1 - Relative Velocity

In order to properly describe an object's motion we need to know...

Example: A man walks to the right with a velocity of 2 m/s on a platform that moves with a velocity of 1 m/s to the right.



a) *What is the person's velocity relative to the platform?*

Reference frame: _____

$v_{\text{person-platform}} = \text{_____ m/s}$

b) *What is the person's velocity relative to the ground?*

Reference frame: _____

$v_{\text{person-ground}} = v_{\text{platform}} + v_{\text{person-platform}}$

$v_{\text{person-ground}} = \text{_____ m/s} + \text{_____ m/s}$

Example: You can throw a pie at 32 m/s. If you are standing on a train traveling 32 m/s east and throw a pie forward what is its resultant (total) velocity?

Example: A bowling team on a train heads **east** at 15 m/s. A stationary observer watches them play as they pass. At what velocity would the following throws appear to be moving at?

Biff: Throws @ 12 m/s East

Hank: Throws @ 18 m/s East

Ralph: Throws @ 15 m/s West

Train A leaves Vancouver station traveling east at 90. km/h at 9:00 am. At the same time train B leaves Montreal traveling west at 110 km/h. If the two stations are 4800 km.

a. At what time do they meet?

b. Where are they when they meet?

If the conductor of train A notices that it takes exactly 3.2 s for train B to pass it, what is the length of train B?

1. A plane is flying round trip to an destination 250 km North of its starting point. The plane flies with an airspeed of 325 km/h and the wind is blowing at 50.0 km/h due North.

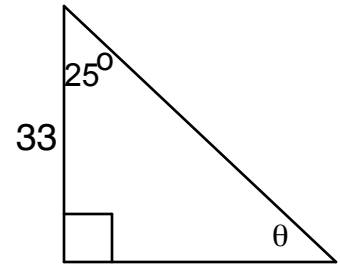
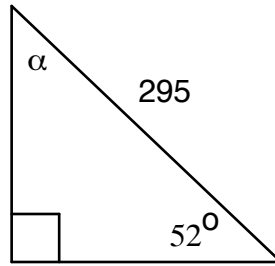
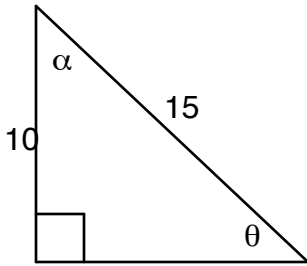
a) How long does it take to get to the destination? b) How long does it take to return to the starting point?

2) A tourist starts at the back of train that is 45 m long and walks towards the front at 1.5 m/s. The train is moving at 12 m/s.

a) How long does it take for the tourist to reach the front of the train, and how far has the tourist moved relative to the ground outside the train by the time they reach the front?

b) If the tourist decides to run all the way back to the end of the train at 6.0 m/s, how far have they travelled relative to the ground outside in this time?

3) Solve the following triangles (**all sides and angles**) using SOH - CAH - TOA and Pythagoras



4) Add the following x and y vectors, draw the **resultant** vector and solve its **magnitude and direction**.

a) x: 3.4 m y: 2.7 m

b) x: 5.6 m/s y: -7.1 m/s

c) x: -211 m y: -44.0 m

Unit 2: Kinematics in 2D
2- Independence of Perpendicular Vectors

Example: After escaping from a maximum security stockade, the A-Team is trying to travel north across a 350 m river in a speed boat. The boat can travel at a speed of 25 m/s in still water and the river flows to the east at 11 m/s.

Part 1: They point their boat directly north across the river.

a. What is their total (resultant) velocity?

b. How long does it take to cross the river?

c. How far down-river do they end up?

Part 2: The Law has caught on to the boys and is waiting down river, on the other side.

a. At what heading should they point the boat so that they land safely, **DIRECTLY** across the river?

b. How long will it take them to cross at this heading?



- Perpendicular vectors are...
- To find the total (resultant) vector we...
- Don't forget that the resultant vector has...
- We don't use...



- 1) Legolas is riding on his stallion going $60. \text{ m/s}$ due North. He pulls out an arrow and notches it. Determine the velocity of his arrow **over the ground** if he fires it at $80. \text{ m/s}$ **relative to the horse**, in the following directions...
 - a) straight ahead (due north)
 - b) To the rear (due south)
- 2) You are down at the railyard at 4:30 AM to watch a taping of an *Alias* episode. You watch as a train goes by at 5.0 m/s south. On top of the train, Agent Sydney Bristow is running north. You see Sydney moving at 8.0 m/s north. At what speed does the camera crew on the train see Sydney running, and in what direction?
- 3) Later during the same shoot the train goes by you at 10.0 m/s south while Sydney runs across a flat bed car at 6.0 m/s west, as far as the camera crew on board is concerned. You are watching from a platform above the train. What is Sydney's velocity from your perspective?
- 4) The Qualicum river flows due west at 4.7 m/s at the spot where Benji, the dog, jumps in and swims at 3.0 m/s , heading straight across, always looking directly at the south bank. Determine the dog's velocity relative to a stationary observer.
- 5) Sir Isaac Newton is bumping along on his pony going 22 m/s due east when he sees his arch-nemesis, Robert Hooke. Newton pulls an apple out of his pocket and hurls it at 40.0 m/s to the north, as far as he is concerned. What is the apple's velocity over the ground?
- 6) Huck Finn's river boat can go 40.0 km/h through the water. The Mississippi River flows due west at 20.0 km/h at the spot where Huck wishes to make a direct crossing to the north side. Determine the heading Huck must take, and the time it will take him to cross the 2.0 km wide Mississippi River.
- 7) Bobo, the clown, can swim at 2.0 m/s . He must make a landing directly across to the north side of the Styx river, which is $100. \text{ m}$ wide. The river flows at 6.0 m/s due east at this point. Bobo's biggest problem is that he can only swim while facing due north. How can he possibly make a landing at the desired location?
- 8) You are in the back of a pickup truck on a warm summer day and you have just finished eating an apple. The core is in your hand and you notice the truck is just passing an open dumpster 7.0 m due west of you. The truck is going 30.0 km/h due north and you can throw that core at 60.0 km/h . In what direction should you throw it to put it in the dumpster, and how long will it take it to reach its destination?

Unit 2: Kinematics in 2D

3 - Vector Addition and Subtraction

SCALAR

VECTOR

Vector Addition

Whenever we add vectors we use...

To find the total or resultant vector, simply draw...

When we draw vectors we represent them as _____.

Ex: A student in a canoe is trying to cross a 45 m wide river that flows due East at 2.0 m/s. The student can paddle at 3.2 m/s.

- If he points due North and paddles how long will it take him to cross the river?
- What is his total velocity relative to his starting point in part a?
- If he needs to end up directly North across the river from his starting point, what heading should he take?
- How long will it take him to cross the river at this heading?

Vector Addition - Trig Method

In the previous example we added perpendicular vectors which gave us a nice simple right triangle. In reality it's not always going to be that easy.

Ex. A zeppelin flies at 15 km/h 30° N of E for 2.5 hr and then changes heading and flies at 20 km/h 70° W of N for 1.5 hr. What was its final displacement?

In order to solve non-right angle triangles, we will need to be familiar with the **Sine Law** and the **Cosine Law**.

Sine Law:



Cosine Law:

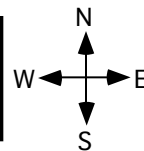
Vector Addition - The Component Method

There is another method that we can use when adding vectors. This method is a very precise, stepwise approach, however it is the only way we can add 3 or more vectors.

- **Draw** each vector
- **Resolve** each vector into x and y components
- Find the **total sum** of x and y vectors
- **Add** the x and y vectors
- **Solve** using trig

REMEMBER: When using x and y components...

Ex. An airplane heading at 450 km/h, 30° north of east encounters a 75 km/h wind blowing towards a direction 50° west of north. What is the resultant velocity of the airplane relative to the ground?



Airplane vector:

x-component

y-component:

Wind vector:

x-component:

y-component:

Adding the two vectors:

x-components of resultant:

y-components of resultant:

Total resultant:

Vector Subtraction

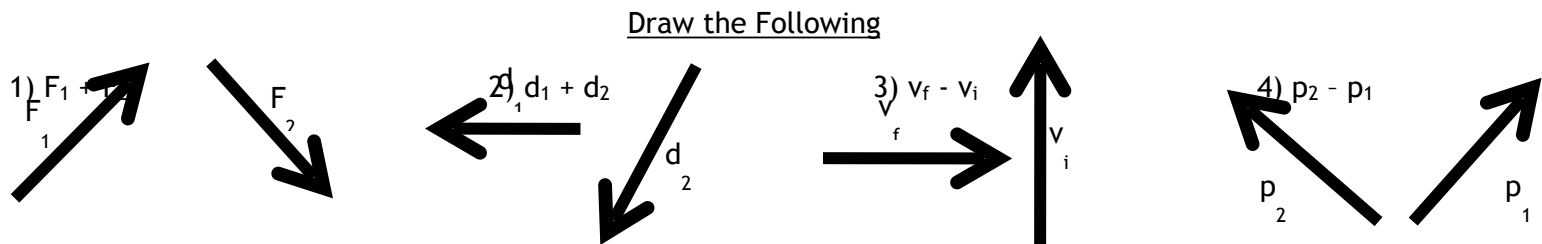
With vectors a negative sign indicates...

When subtracting vectors we still draw them *tip to tail*, except...

We generally subtract vectors when dealing with a _____ in a vector quantity.

Recall:

Change =



Ex: A cyclist is traveling at 14 m/s west when he turns due north and continues at 10 m/s. If it takes him 4.0 s to complete the turn what is the magnitude and direction of his acceleration?

Unit 2: Kinematics in 2D
4 - Projectile Motion Types 1 and 2

Remember that the x and y-components are _____ and therefore totally

X-components

There is no _____ working on the projectile in the X and the acceleration is always _____. Therefore the only equation we can ever use is:

Y-components

In this case there is always a constant acceleration of _____. Because of this we need to use the _____.

The only value that can ever be used on both sides is _____ because it is a

Problem Type 1:

A student sits on the roof of their house which is 12 m high. She can launch water-balloons from a slingshot at 14.0 m/s. If she fires a water-balloon directly horizontally:

a. How long will it be airborne?

This depends on:

b. How far forward will it travel?

This depends on:

Example: A Cutlass Supreme drives straight out of a parking garage at 8.0 m/s and hits the water 3.4 s later.

a. How far did the car fall?

b. What was his **total** impact velocity? (magnitude and direction)

Problem Type 2: The Dukes of Hazzard are traveling at 85 km/h when they hit a jump that makes an angle of 25° above the horizontal.

- a. How long are they airborne?
- b. How far forward do they fly through the air?
- c. What is their maximum height?

Example: A quarterback launches a ball to his wide receiver by throwing it at 12.0 m/s at 35° above horizontal.

- a. How far downfield is the receiver?
- b. How high does the ball go?
- c. At what other angle could the quarterback have thrown the ball and reached the same displacement?

Problem Type 3:

Ex: A cannon is perched on a 48 m high cliff. It aims 30° above the horizontal and fires a shell at 52 m/s. Find:

- a) How long it takes for the shell to hit the ground.
- b) The distance it lands from the base of the cliff.

Ex: A BMXer leaves a ramp traveling at 65 km/h at a trajectory of 40° above the horizontal. He strikes the top of a building 5.8 m above the ground.

- a) What is the horizontal distance from the ramp to the building?
- b) What is his speed when he hits the building?

Unit 2: Kinematics in 2D

5 - Projectile Motion More Practice!

Projectiles in 2-D - x and y components are _____ and therefore totally _____.

X-components

- No _____ in the x direction
- _____ is always zero
- The only equation you can ever use is:

Y-components

- Always a constant acceleration of _____
- _____
- Need to use the Big 3 equations

The only value that can ever be used on both sides is _____ because it is _____

2

Ex 1: A student sits on the roof of their house which is 12 m high. She can launch water-balloons from a slingshot at 25 m/s. If she fires a water-balloon directly horizontally:

a. How long will it be airborne?

* *How long it is airborne only depends on:* _____

* *How far it travels in the x-direction depends only on:* _____ and _____

Ex 2: A quarterback launches a ball to his wide receiver by throwing it at 22.0 m/s at 35° above horizontal.

- a. How far downfield is the receiver?
- b. How high does the ball go?
- c. At what other angle could the quarterback have thrown the ball and reached the same displacement?

Ex 3: A cannon sits on a 65 m high cliff (typical Trask...so typical...). A cannonball is fired at 42 m/s 55° above the horizontal.

- a. How long is it airborne?
- b. What is its final velocity?
- c. What is its maximum height relative to the ground below?