*Friction and air resistance are negligible

Scalars and vectors

1. An object is launched at an angle 30° above the horizontal surface with an initial velocity of 50 m/s.
    a. Determine the horizontal and vertical components of the initial velocity.
2. Given two vectors $A = 6i + 8j$ and $B = -12i + 5j$.
    a. Calculate the product of $A \cdot B$.
    b. Determine the angle between the vector A and B.
3. Two cars are moving in the same direction on a straight road. Car A is moving $60\ km/h$ and car B is $95\ km/h$.
    a. Determine the relative velocity of Car B to Car A.
    b. If the initial distance between them is $900\ m$, how long will it take for Car B to overtake Car A?
4. A projectile is launched with an initial velocity $50 m/s$ at an angle 60° above the horizontal surface.
    a. Draw a graph to break down the initial velocity into horizontal and vertical components.
    b. Calculate the maximum height reached by the projectile.
    c. Determine the total time the projectile is in the air.
5. A boat sails 30 kilometers east and then turns to sail 40 kilometers north.
    a. Represent the boat's total displacement as a vector.
    b. Calculate the magnitude and direction of the displacement vector.
    c. Determine the average speed if the boat took 2 hours for the entire trip.
6. A 12-meter ladder is leaning against a wall, making an angle 45° with the ground.
    a. Determine the height at which the ladder touches the wall.
    b. Calculate the distance between the base of the ladder and the wall.
7. A particle moves 5 meters east and then 3 meters north.
    a. Represent the particle's displacement as a vector using unit vectors j (north) and i (east).
    b. Calculate the magnitude and direction of the resultant displacement vector.

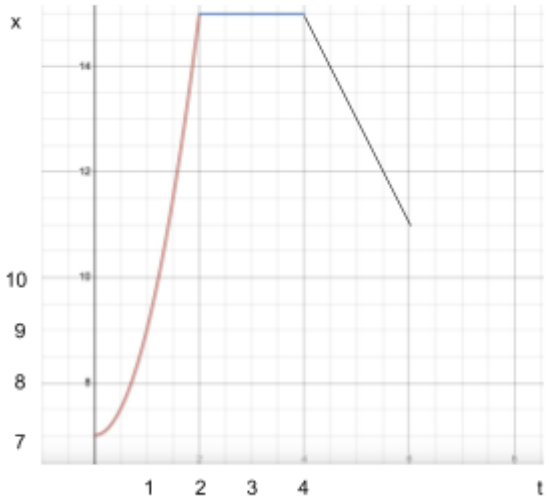
Displacement, velocity, and acceleration

1. A car accelerates uniformly from $30\ m/s$ at $5\ m/s^2$ for 8 seconds. Calculate the final velocity of the car after 8 seconds.
2. A rock dropped from a 150 m cliff stops in 0.2 seconds after hitting the ground. What is the acceleration of the rock directly after hitting the ground?

3. The acceleration of a ball that started at rest at position $x_i = 3$ m on a flat surface is defined by $a(t) = 3t - 9$.
    a. Find $v(t)$.
    b. What is the ball's velocity at $t = 3$?
    c. What is the average velocity of the ball during the time interval $1 \leq t \leq 3$?
    d. Find $x(t)$.
    e. Find the position of the ball at $t = 4$.
    f. What is the displacement of the ball during the time interval $2 \leq t \leq 4$?
4. A person threw a rock horizontally from the cliff with an initial velocity of $8\ m/s$. The cliff is 80 meters to the ground.
    a. When does the rock hit the ground?
    b. What is the highest velocity for the rock?
5. A police officer is driving at $30\ m/s$, chasing a robber's car 400 meters ahead. The robber is driving at 40 m/s and accelerating at 5 m/s². The robber is 700 meters from the state border. The police officer wants to catch the robber before he crosses the border. Ignoring the time it takes to start accelerating, what acceleration must the police car have to catch the robber in time?
6. A zombie on a cliff throws a javelin up at an angle of 30° above the horizontal with an initial velocity of 50 m/s, and he hears the javelin hit the ground after 30 seconds, the javelin travels a horizontal displacement of 10000 m. The speed of sound in the air is 343 m/s. Sound travels in a straight line.
    a. Find the height of the cliff.
    b. Aliens use lasers to melt half of the cliff's height, forcing the zombie to throw the javelin at an angle of 45° and an initial velocity of 40 m/s. How many seconds after the rock is thrown can he hear it hitting the ground?
7. A football player kicks a ball that is initially on the ground. The ball leaves the ground with an initial speed of 20 m/s at an angle of 60° to the horizontal and travels toward a vertical wall. The ball hits the wall the moment it reaches a vertical component of velocity of 0 m/s and bounces back with the same horizontal speed.
    a. What is the horizontal distance between the ball and the building?
    b. The football player re-positions himself to a point of a horizontal distance of 40 m away from the building with the same elevation and kicks the ball again with an initial velocity of angle 60°. The height of the wall under the window is 40 meters. The height of the window is 2 m. What is the interval of initial velocity that he needs to kick the ball to ensure that it hits the window?

8. An artilleryman is conducting target shooting training. The bullseye and the muzzle are on the same horizontal plane. The horizontal distance between the bullseye and the muzzle is 3000 meters. The initial velocity of the cannonball is $250\ m/s$. The cannonball hits the bullseye 15 seconds later.
    a. What is the shooting angle?
    b. If the target moves away from the muzzle in a straight line at a horizontal acceleration of 4 meters per second after the cannonball is launched, and the cannonball hits the bullseye 20 seconds later with the initial acceleration unchanged, the bullseye is still 3000 meters away from the muzzle before moving. What should the launch angle be?

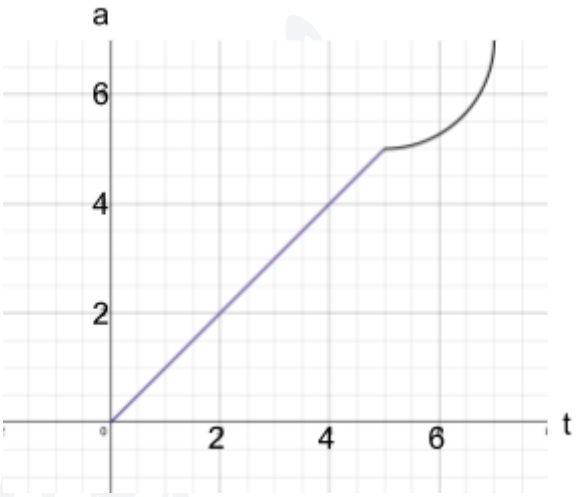
Representing motion



1. Reference the graph to the right.
    a. Find the displacement during the time interval $0 \leq t \leq 8$.
    b. Find the velocity at $t = 7$.
    c. Find the acceleration at $t = 7$.
    d. Find the velocity at $t = 3$.
    e. Find the acceleration at $t = 5$.
    f. Find the average velocity during the time interval $0 \leq t \leq 8$.
    g. Sketch the graph of velocity and acceleration.
2. Reference the graph to the right.
    a. Find the displacement during the time interval $0 \leq t \leq 10$.

b. Find the velocity at $t = 2$.
c. Find the acceleration at $t = 2$.
d. Find the velocity at $t = 9$.
e. Find the acceleration at $t = 9$.
f. Find the average acceleration during the time interval $0 \leq t \leq 10$.
g. Sketch the graph of displacement and acceleration

3. Reference the graph to the right.
   a. Find the velocity during the time interval $0 \leq t \leq 7$.
   b. Find the acceleration at $t = 4$.
   c. Find the Jerk at $t = 2$.
   d. Find the acceleration at $t = 6.75$.
   e. Find the average jerk during the time interval $0 \leq t \leq 7$.
   f. Sketch the graph for jerk and velocity.



Reference Frames and Relative Motion

1. A 330-meter-long train moves at a constant speed of $25\ m/s$ towards a $200\ m$ bridge. When the front of the train reaches the beginning of the bridge, a pedestrian starts walking from the end towards the train at a speed of $12\ m/s$.
   a. Determine the time it takes for the train to cross the bridge completely.
   b. Calculate how far the pedestrian has walked by the time the train has wholly crossed the bridge.
2. A boat is attempting to cross a 500-meter-wide river. The boat can move at $10\ m/s$ relative to the water. However, the river's current flows at $3\ m/s$ downstream.
   a. What is the resultant velocity of the boat relative to the ground if the boat points directly across the river?
   b. How far downstream will the boat land from its starting point?
   c. What heading should the boat take to land directly opposite its starting point?

3. An airplane is flying with an airspeed of $250\ km/h$ in a direction 30° north of east. There is a wind blowing from the west at $100\ km/h$.
    a. Determine the ground speed of the airplane.
    b. Calculate the direction of the airplane's actual path over the ground.
4. A person walks on a moving walkway in an airport. The walkway moves east at $2\ m/s$, and the person walks west at $1.5\ m/s$ relative to the walkway.
    a. What is the person's velocity relative to the ground?
    b. If the walkway is 100 meters long, how long does it take for the person to walk from one end to the other relative to the ground?
5. Car A travels east at $60\ km/s$, and Car B travels west at $80\ km/s$. They are initially 200 kilometers apart.
    a. How long will it take for the two cars to meet?
    b. If a bird starts flying from Car A towards Car B at $100\ km/s$, flying back and forth between the two cars until they meet, how far does the bird travel?
6. A skateboarder stands on a train platform. A train moving west at $15\ m/s$ passes by. As the train passes, the skateboarder starts moving east at $5\ m/s$ relative to the ground.
    a. What is the skateboarder's velocity relative to the train?
    b. If the train is 300 meters long, how long does it take for the skateboarder to walk from the back to the front of the train?
7. In reference frame S, a projectile is launched horizontally with a speed of $20\ m/s$ from the top of a 45-meter-high cliff. Reference frame S' is moving east at $10\ m/s$ relative to S.
    a. Determine the horizontal distance the projectile travels before hitting the ground as measured in frame S.
    b. What is the horizontal velocity of the projectile as observed from frame S'?
8. Cyclist X travels north at $12\ km/h$, and Cyclist Y travels west at $16\ km/h$. They start from the same point and move away from each other.
    a. What is the rate at which the distance between the two cyclists increases?
    b. After 2 hours, how far apart are the two cyclists?
9. A rocket is launched vertically upward with a velocity of $50\ m/s$ relative to the ground. Simultaneously, a strong horizontal wind blows east at $20\ m/s$.
    a. Describe the rocket's motion relative to the ground.
    b. If the rocket engine shuts off after 5 seconds, what will be its velocity relative to the ground at that instant?
10. Two runners start from the same point at the same time. Runner A runs east at $8\ m/s$, and Runner B runs north at $6\ m/s$.
    a. After 10 seconds, what is the distance between the two runners?
    b. At what time will the runners be exactly 100 meters apart?