Section 3: Kinematics

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Physics TAC §112.39(c).

3.01 Distance and Displacement

Note: This section requires use of trigonometry.

- Physics (4)(B)

3.02 Average Speed and Average Velocity

Note: This section requires use of trigonometry.

- Physics (4)(B)

3.03 Kinematic Equations in One Dimension

- Physics (4)(B)

3.04 Kinematic Equations Graphical Analysis

- Physics (3)(A)
- Physics (4)(A)

3.05 Kinematic Equations in Two Dimensions

Note: This section requires use of trigonometry.

- Physics (4)(C)

3.06 Relative Motion

Note: This section requires use of trigonometry.

- Physics (4)(F)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.

3.01

Distance and Displacement

Distance – a ___________________ quantity measuring the total length traveled on a particular trip from point A to point B

Displacement – a __________________ quantity measuring the length and direction of the shortest straight-line path from point A to point B

Ways of Expressing Distance and Displacement

- Distance contains only a magnitude (with units).

- Displacement always contains both magnitude (with units) and direction.

1. Suppose Chloe walks 80 m north and then 30 m west. Calculate Chloe's distance and displacement. Express her displacement three different ways.

2. Suppose Johnny walks 100 m north, then 50 m west, then 80 m south, then 50 m east, and then 20 m south. Calculate Johnny's distance and displacement.

3.02

Average Speed and Average Velocity

Average Speed – a __________________ quantity equal to the total distance traveled divided by the total time elapsed

Average Velocity – a ___________________ quantity equal to the displacement divided by the time elapsed

1. Suppose a car drives 20 km northbound on the interstate in 10 minutes. Calculate its average speed and average velocity.

2. Suppose an airplane travels 60 km north and then makes a hard right and travels 35 km east. The entire process takes 30 minutes. Calculate the airplane's average speed and average velocity.

3. Suppose my average velocity for the past minute was equal to zero. Which of the following is true? Select all that apply.

   A. I traveled zero distance over the last one minute.
   B. My average speed was zero over the last one minute.
   C. I traveled more than zero distance over the last one minute.
   D. My average speed was more than zero over the last one minute.
   E. My displacement was zero over the last one minute.

3.03

Kinematic Equations in One Dimension

$$v_f = v_i + at$$

$$\Delta x = v_i t + \frac{1}{2}at^2$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

Kinematic Variables

- Δx represents ___________________________________.
- v_i represents ___________________________________.
- v_f represents ___________________________________.
- a represents ___________________________________.
- t represents ___________________________________.
- The kinematic equations are valid *only* over intervals of constant ___________________.

STUDY EDGE TIP

Think carefully about what "initial" and "final" mean!

1. Suppose the Tesla Model S P100D, an electric car, in "Ludicrous Mode" can accelerate at a rate of $11.8\,\frac{\mathrm{m}}{\mathrm{s}^2}$. If this rate of acceleration is constant, how long does it take for the Model S to get from rest to $26.8\,\frac{\mathrm{m}}{\mathrm{s}}$ ($60\,\frac{\mathrm{mi}}{\mathrm{hr}}$)?

2. How far does the Model S from question 1 travel during this time?

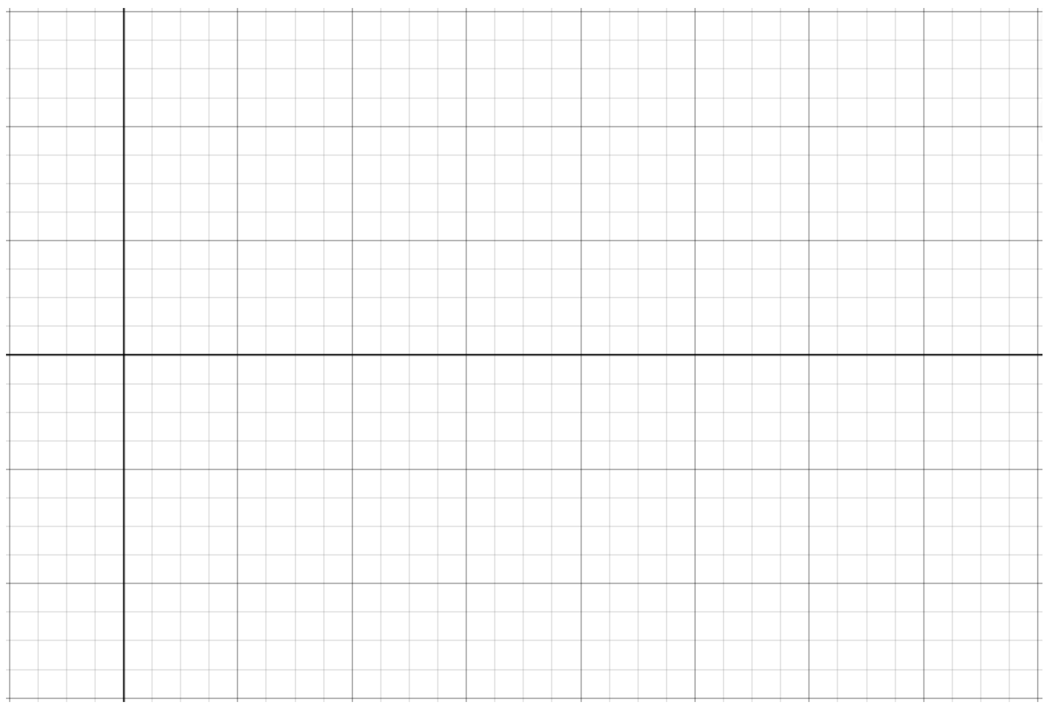
3. Starting at a speed of $20\,\frac{\mathrm{m}}{\mathrm{s}}$, suppose a train abruptly brakes. The train accelerates uniformly to rest over a distance of $1\ \mathrm{km}$. What is the rate of acceleration of the train during this time?

3.04

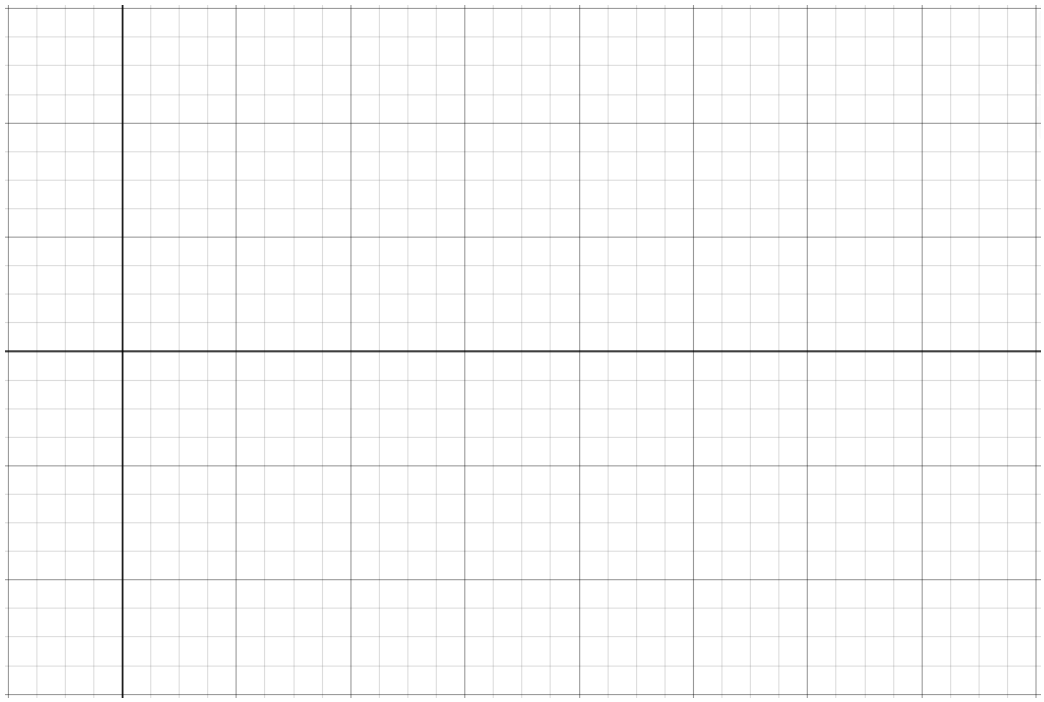
Kinematic Equations Graphical Analysis

1. Suppose a skateboarder coasts at constant velocity on smooth pavement, and graphs of her motion are generated. Predict how these graphs would appear.

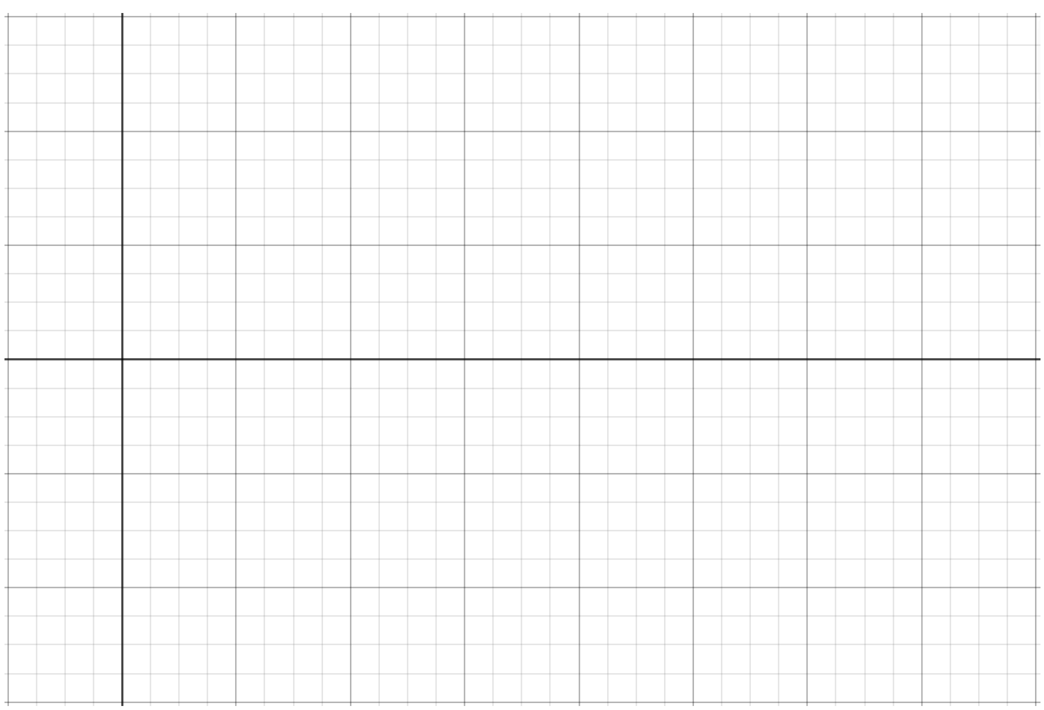
   i. Position versus time



ii. Velocity versus time

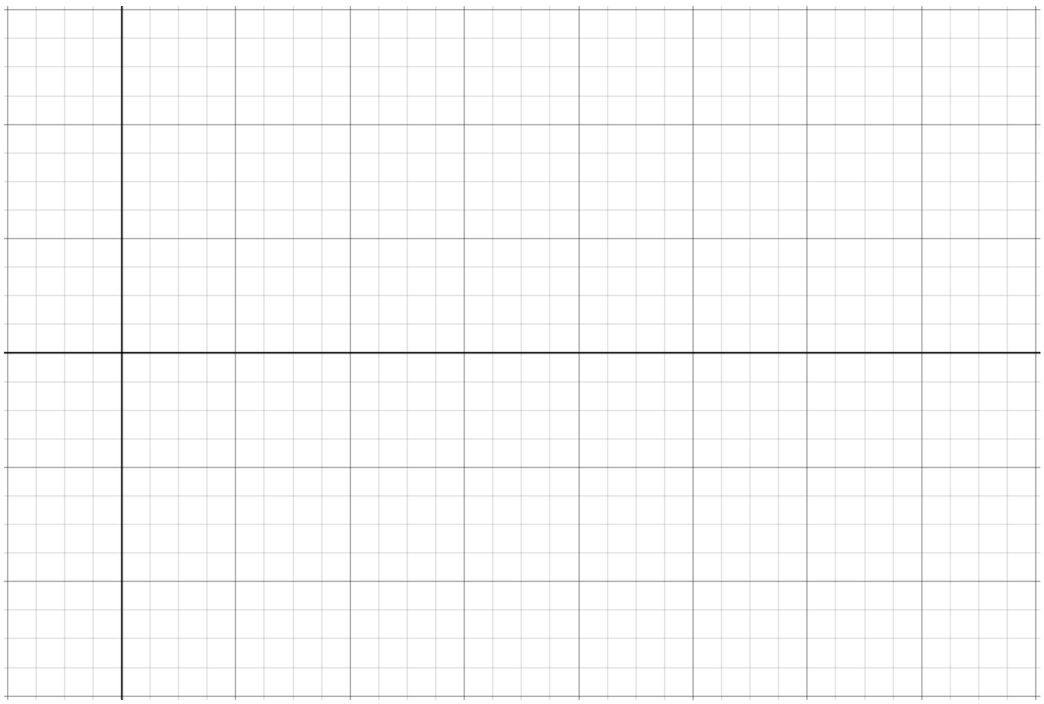


iii. Acceleration versus time

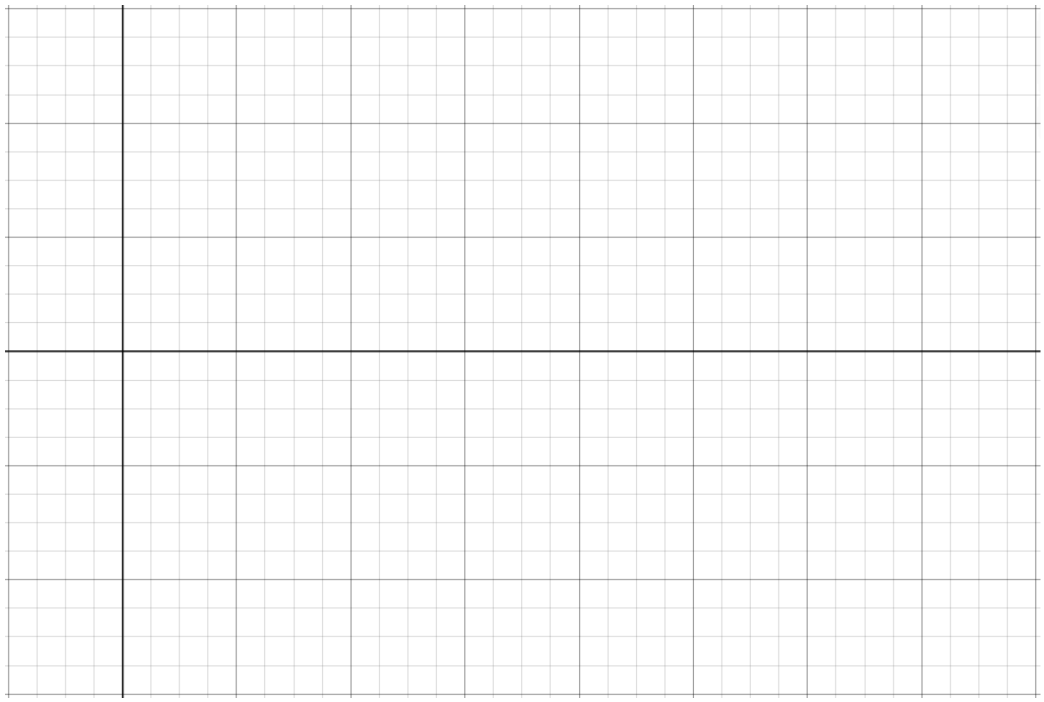


2. Suppose a car is following behind a slow truck on the highway, and both vehicles are traveling $10\,\frac{\mathrm{m}}{\mathrm{s}}$. The driver of the car becomes frustrated by the low speed and carefully moves into the next lane to begin accelerating at a constant rate of $2\,\frac{\mathrm{m}}{\mathrm{s}^2}$ to overtake the truck. Graphs of the car's motion are generated beginning as soon as it switches lanes. Predict how these graphs would appear.

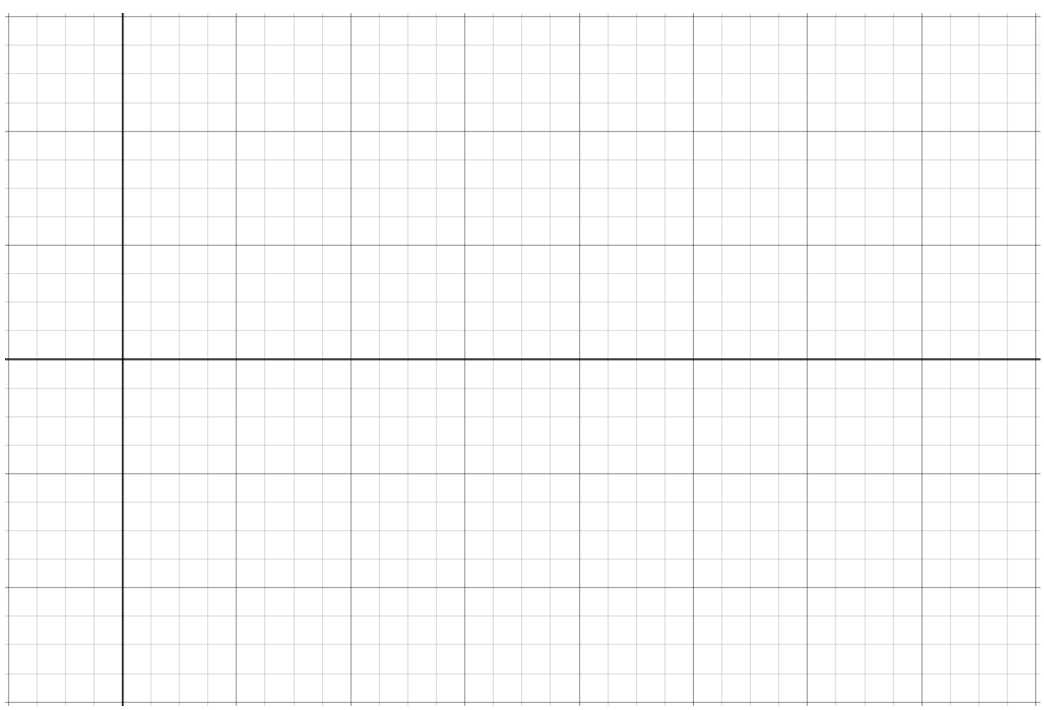
    i. Position versus time



ii. Velocity versus time



iii. Acceleration versus time



- The slope of a *position versus time* graph represents ____________________________.
- The slope of a *velocity versus time* graph represents ____________________________.
- The area between the *x* axis and the curve on a *velocity versus time* graph represents change in _________________________.
- The area beneath an *acceleration versus time* graph represents change in _________________________.

3.05

Kinematic Equations in Two Dimensions

$$v_{fx} = v_{ix} + a_x t$$
$$\Delta x = v_{ix} t + \frac{1}{2} a_x t^2$$
$$v_{fx}^2 = v_{ix}^2 + 2a_x \Delta x$$

$$v_{fy} = v_{iy} + a_y t$$
$$\Delta y = v_{iy} t + \frac{1}{2} a_y t^2$$
$$v_{fy}^2 = v_{iy}^2 + 2a_y \Delta y$$

Projectile – an object under the influence of _______________________ but ***not*** under the influence of any other forces

- The acceleration of a projectile near Earth's surface, in the y-direction, is approximately _______________________ toward the Earth's center.
- The acceleration of a projectile in the x-direction is always __________________.
- The flight path of a projectile in motion traces the shape of a __________________.

1. Suppose a cannon sits on top of a tower with a height of 25 m and launches a cannonball at an angle of $40°$ above the horizontal at a speed of $35 \frac{\text{m}}{\text{s}}$. Ignoring air resistance, calculate how *far* the cannonball lands from the base of the tower, and calculate the maximum *height* (measured from the ground) attained by the cannonball during its flight.

3.06

Relative Motion

When an object is traveling at a certain velocity, that velocity is implicitly measured *relative to* something else. For example, if two bicyclists are riding next to each other at different speeds, in the same direction, past a stationary observer, the question of how fast each is going depends on the perspective of the person performing the measurement.

1. Suppose a professional baseball player is capable of pitching at $95\,\frac{\mathrm{mi}}{\mathrm{hr}}$ $(42\,\frac{\mathrm{m}}{\mathrm{s}})$. Suppose this baseball player is also an avid physicist and agrees to go skydiving as part of a physics experiment on relative motion. While skydiving, he falls at a rate of $55\,\frac{\mathrm{m}}{\mathrm{s}}$ and pitches a fastball upward toward the sky. What is the speed of the ball, relative to the stationary helicopter he jumped out of? What is the speed of the ball relative to the ground? What is the speed of the ball relative to the baseball player?

2. Suppose a boat called the S.S. Anne is to cross a $1\ \mathrm{km}$-wide river and reach a port directly north of its starting position on shore. The river flows due west at a constant speed of $3\,\frac{\mathrm{m}}{\mathrm{s}}$ relative to the shore. If the S.S. Anne's motors can propel the boat at $8\,\frac{\mathrm{m}}{\mathrm{s}}$ relative to the water, what direction should the captain steer the boat in order to reach the destination port as efficiently as possible?