Name: ____________________

Physics 20 – Topic 2

Motion in 1D (Kinematics)

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Title	Due Date
Displacement	
Velocity	
Lab: Motion of a Rolling Ball	
Lab: Motion of a Bouncing Ball	
Accelerated Motion	
Uniform Accelerated Motion	

DISPLACEMENT

Mechanics

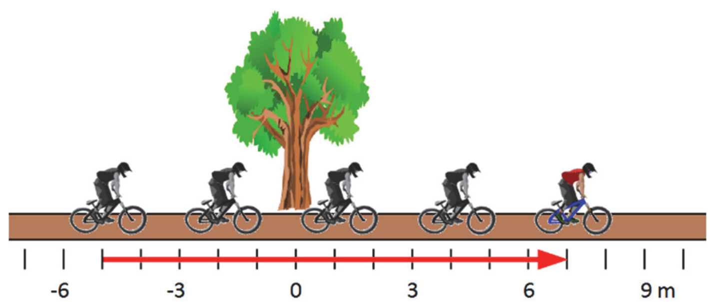
The study of motion is called **mechanics**. There are two main branches of mechanics:

- **Kinematics** involves *describing how* objects move. We will be studying kinematics for one-dimensional motion in this topic.
- **Dynamics** involves *explaining why* objects move the way they do. We will study dynamics a bit later in the course.

Position

When we describe an object's motion, we first need to be able to describe where the object is: this is called the object's **position**.

- When an object moves only in a straight line (either forward or backward), we call this **one-dimensional (1D) motion**, because we only need to make one measurement to describe the position. A measurement that describes a position is called a **coordinate**.
- The **origin** is an arbitrarily chosen point which is assigned a coordinate of exactly 0. The object's position is represented by its distance from the origin, with the positions on one side of the origin assigned positive values and the other side of the origin assigned negative values.
- The symbol for position is $\vec{\mathbf{d}}$ and the SI unit is metres (m). In the illustration below, the bike's initial position is $\vec{\mathbf{d}}_i = -5.0\text{ m}$ and its final position is $\vec{\mathbf{d}}_f = +7.0\text{ m}$. The illustration uses the tree as the origin: the bike is initially 5.0 metres to the left of the tree, and after some time it has moved to 7.0 metres to the right of the tree.



We can summarize the motion in a data table. If the time between measurements is 1.0 second, the complete data table would be:

Time, t / s	Position, $\vec{\mathbf{d}}$ / m
0.0	−5.0
1.0	−2.0
2.0	+1.0
3.0	+4.0
4.0	+7.0

Displacement

The *change* in an object's position between any two points on its trajectory is called the **displacement**. The symbol for displacement is $\Delta\vec{\mathbf{d}}$:

$$\Delta\vec{\mathbf{d}} = \vec{\mathbf{d}}_f - \vec{\mathbf{d}}_i$$

- The bicycle's displacement for the entire 4.0-second time interval is:

$$\Delta\vec{\mathbf{d}} = (+7.0\text{ m}) - (-5.0\text{ m}) = +12.0\text{ m}$$

- Displacement is represented on the diagram by the red arrow connecting the initial and final positions. The displacement of +12.0 m means that the read arrow is 12.0-metres long and points in the positive direction.
- Displacement is classified as a **vector** quantity because it involves a **direction** as well as a **magnitude** (size). The bike's displacement in the example above has a magnitude of 12.0 metres and the direction is positive.

Vector Diagrams

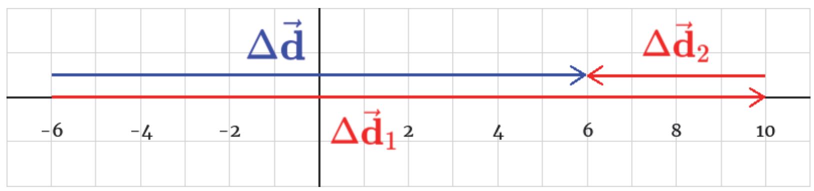
When the motion contains more than a single displacement, the **vector diagram** consists of all displacements drawn in a “tip-to-tail” manner. (See the example below.)

- The **resultant** (total) displacement is drawn from the starting position of the first vector to the final position of the last vector.
- The displacement is **not** always the same as the **distance** travelled by the object. If the motion involves any change in direction (it does not follow the most direct route), the distance travelled will be more than the magnitude of the displacements.
- Distance is a **scalar**; it does not have a direction.

Example

1. A student walks from an initial position of –6.0 m to +10.0 m, and then back to +6.0 m. Calculate the displacement and the distance walked.

First draw the vector diagram:



Next calculate the two parts of the displacement using $\Delta\vec{d} = \vec{d}_f - \vec{d}_i$:

$$\Delta\vec{\mathbf{d}}_1 = +10.0\text{ m} - (-6.0\text{ m}) = +16.0\text{ m}$$

$$\Delta\vec{\mathbf{d}}_2 = +6.0\text{ m} - (+10.0\text{ m}) = -4.0\text{ m}$$

Since distance is a scalar, we ignore the directions and just add the magnitudes:

Distance = $|\Delta\vec{\mathbf{d}}_1| + |\Delta\vec{\mathbf{d}}_2| = 16.0\text{ m} + 4.0\text{ m} = 20.0\text{ m}$

To get the resultant displacement, add the vectors with the directions included:

$$\Delta\vec{\mathbf{d}} = \Delta\vec{\mathbf{d}}_1 + \Delta\vec{\mathbf{d}}_2 = +16.0\text{ m} + (-4.0\text{ m}) = +12.0\text{ m}$$

Alternatively, we could just subtract the initial and final positions:

$$\Delta\vec{\mathbf{d}} = \vec{\mathbf{d}}_f - \vec{\mathbf{d}}_i = +6.0\text{ m} - (-6.0\text{ m}) = +12.0\text{ m}$$

Practice

Answer these questions on a separate sheet of paper, showing all work. Be sure to write your name and the lesson title on your work and keep the completed assignment in your Physics 20 binder. Keep your binder organized (i.e. assignments in the correct order) so that it will be easy to find assignments when required.

Use the grids provided on the handout for your vector diagrams. Be sure to indicate the scale of each diagram.

2. A hiker moving in 1D has an initial position of –4.0 km and a final position of +3.2 km relative to some arbitrary origin.

   a) Draw and label a vector diagram of the hiker’s motion.

   b) Calculate the hiker’s displacement. Show your work.

   c) The hiker now walks to a third position of +1.0 km. Draw a new vector diagram showing both parts of the motion and the resultant displacement.

   d) Calculate the resultant displacement and the total distance the hiker walked.

3. A cyclist located 12 km [north] of his home undergoes a displacement of 25 km [south]. Draw a vector diagram of the motion and determine the cyclist’s final position. Use the cyclist’s home as the origin.
4. A student rides her bicycle 5.00 km north in 12.0 min. After a 5.0 min rest, she rides back south to her starting point in 15.0 min. Determine the student’s *displacement* and *distance* traveled for the entire trip.

Velocity

Velocity

The *rate* of displacement (the displacement per second) is called the **velocity** of the object:

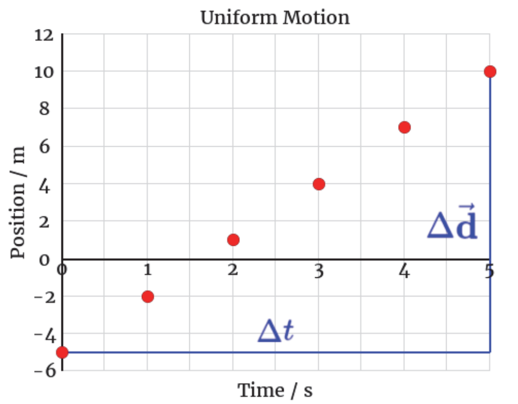
$$\vec{\mathbf{v}} = \frac{\Delta\vec{\mathbf{d}}}{\Delta t}$$

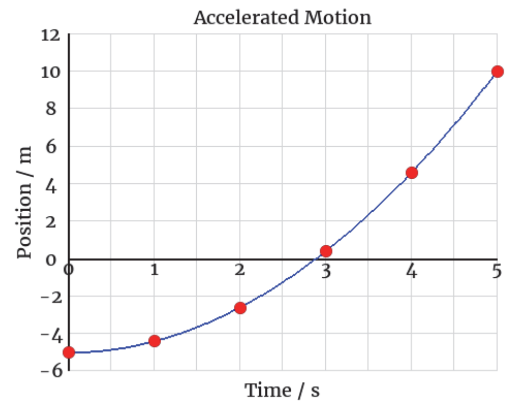
- Like displacement, velocity is a *vector* because it has a direction.
- Velocity is measured in metres per second (m/s).
- Convert km/h to m/s by dividing by 3.6.
- Convert km/s to m/s by multiplying by 1000.

Motion Graphs

If we have a graph of an object's position ($\vec{\mathbf{d}}$) versus time (t), the velocity equation is identical to the *slope*; $\Delta\vec{\mathbf{d}}$ is the "rise" and Δt is the "run".

- Both graphs below illustrate a total displacement of +15.0 metres (from –5.0 to +10.0 m) over a time of 5.0 seconds, giving a velocity of +3.0 m/s. The graph on the left is from the Bicycle data from the last lesson.





Knowing that slope represents the velocity, we can interpret motion graphs ($\vec{\mathbf{d}}$-t) as follows:

- Upward slope means forward motion (positive velocity); downward slope means reverse motion (negative velocity).
- Steep sections of a graph indicate a fast velocity; shallow segments indicate a slower velocity.
- Straight segments of the graph have *constant* velocity. This type of motion is called **uniform motion**. (*For the graph on the left, the position changes by +3.0 m over every 1-second interval.)*
- Horizontal (flat) segments indicate an object at rest ($\vec{\mathbf{v}} = 0$).
- Curved parts of the graph indicate that the velocity is changing. This is called **accelerated motion**. (*For the graph on the right, the position changes slowly at the beginning and more rapidly at the end, as shown by the steepness of the curve.)*
- If the graph curves in such a way as to get steeper with time, the object is speeding up. The graph will get flatter over time when the object is slowing down.
- **Instantaneous** velocity means the velocity calculated between two points that are so close together that the curve of the graph has negligible effect on the result.
- **Average** velocity is calculated over an extended time period. (*The two graphs have the same average velocity, but the graph on the right has a different instantaneous velocity at different times.)*

Speed

An object's **speed** is the *distance* travelled per second:

$$v = \frac{\Delta d}{\Delta t}$$

- Speed is a *scalar*.
- Because the distance travelled is often greater than the displacement (unless the motion is by the shortest possible path), the average speed will often be greater than the velocity's magnitude.

Practice

Answer these questions on a separate sheet of paper, showing all work. Be sure to write your name and the lesson title on your work and keep the completed assignment in your Physics 20 binder. Keep your binder organized (i.e. assignments in the correct order) so that it will be easy to find assignments when required.

1. How long will it take an aircraft that travels at 425 km/h to fly 550 km from Edmonton to Saskatoon?
2. A car drives from Edmonton to Calgary, a displacement of 285 km [south], in 3.25 hrs. What is the car's average velocity?
3. A hiker follows a circular path, walking at an average *speed* of 5.00 km/h. After 3.20 hours of walking, he returns to his starting point, finishing one complete lap.

   a) What is the hiker's *distance* traveled?

   b) What is the hiker's *displacement* and *average velocity*?

   c) Calculate the hiker's average velocity and his average speed.

4. A long-distance runner maintains an average speed of 12.0 km/h while training. If she runs for 85.0 min, what distance did she cover?
5. Over a 25.0 km course, a runner wants to maintain an average speed of 15.0 km/h. At the halfway point (i.e. 12.5 km) of the course, her time is 57.0 min.

   a) What is the runner's *desired* finishing time?

   b) How much time did it take her to run the first half of the course?

   c) What average speed does the runner need to maintain over the second half of the course to finish the race in her desired time?

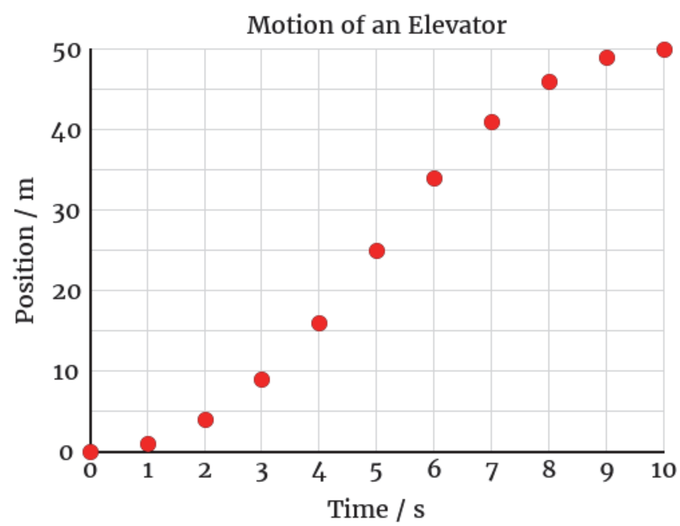
6. The graph illustrates the motion of an elevator ascending inside a tall building.

   a) Based on the appearance of the graph, is the motion of the elevator *uniform* or *accelerated*? Explain.

   b) *Describe* the motion of the elevator in terms of its position and velocity.

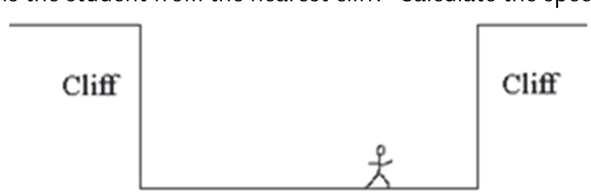
   c) Calculate the *average* velocity of the elevator for the entire 10 seconds.

   d) At what time did the elevator have the greatest *instantaneous* velocity? How do you know?



   e) Calculate the *instantaneous* velocity at the point you identified as having the greatest velocity.

7. Physics 20 students are on a field trip to measure the speed of sound when one of the students gets lost and yells "Help!" The student hears the echo of his voice from the near cliff after 1.10 s and from the far cliff in 2.50 s. (The student had a stopwatch.) The student remembers that the two cliffs are 600 m apart. How far is the student from the nearest cliff? Calculate the speed of sound.

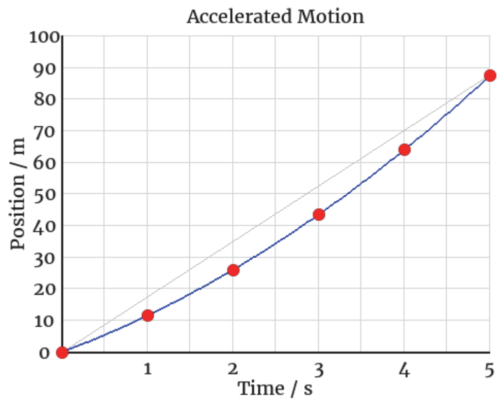


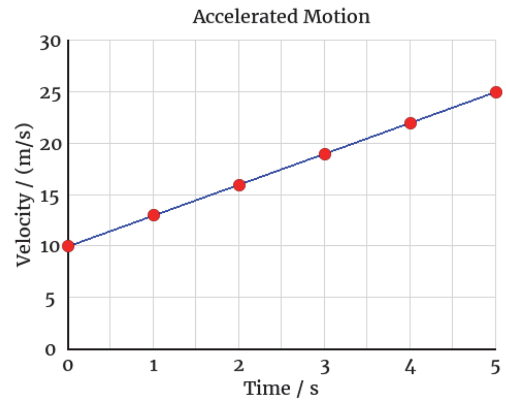
ACCELERATION

Accelerated Motion

Motion with a velocity that is *changing* is called **accelerated motion**.

- The $\vec{\mathbf{d}}$-t graph will be curved for accelerated motion.
- The $\vec{\mathbf{v}}$-t graph may be curved or linear, but it will not be horizontal for accelerated motion.





Acceleration

The *rate* at which an object's instantaneous velocity changes is called its **acceleration**:

$$\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t} = \frac{\vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i}{\Delta t}$$

- This equation describes the *slope* of the $\vec{\mathbf{v}}$-t graph. An upward slope indicates a positive acceleration, a downward slope indicates a negative acceleration, and a constant slope (linear graph) indicates the acceleration is constant.
- Speeding up, slowing down, and changing direction are all examples of acceleration.
- Near Earth's surface, the acceleration due to gravity is –9.81 m/s^2, where the negative sign indicates a downward direction. All objects accelerate at this rate when Earth's gravity is the only force acting on the object. If there is air resistance, an applied force, or any other force besides gravity, the acceleration will be different.

Example

1. An apple, initially at rest, falls from a tree and takes 0.800 seconds to reach to the ground.

   a) Calculate the apple's velocity as it strikes the ground.

   Rearrange the acceleration equation to isolate $\vec{\mathbf{v}}_f$:

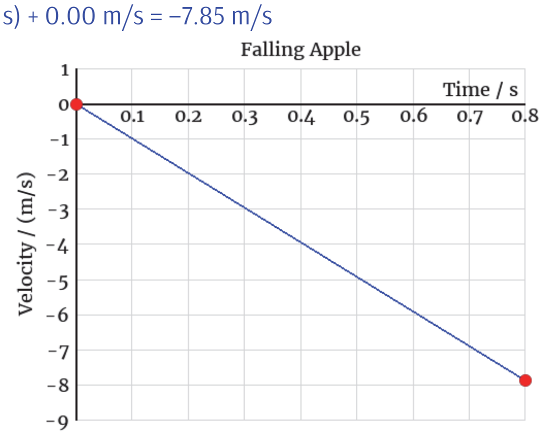
   $$\vec{\mathbf{a}}\Delta t = \vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i \rightarrow \vec{\mathbf{v}}_f = \vec{\mathbf{a}}\Delta t + \vec{\mathbf{v}}_i$$

   Evaluate, assuming the acceleration is solely due to gravity:

   $$\vec{\mathbf{v}}_f = -9.81\ \text{m/s}^2\ (0.800\ \text{s}) + 0.00\ \text{m/s} = -7.85\ \text{m/s}$$

   b) Draw a graph of the velocity versus time.

   Because the acceleration is constant, the velocity graph must be a straight line. We can simply plot the initial and final velocities and connect the two points with a straight line.

   c) Estimate the height from which the apple fell.

   Since the apple accelerates from $\vec{\mathbf{v}}_i$ = 0.00 m/s to $\vec{\mathbf{v}}_f$ = –7.85 m/s, we can <u>estimate</u> the average velocity as halfway between these two values: $\vec{\mathbf{v}}_{avg} \approx -3.92$ m/s. This allows us to estimate the displacement:

   $$\Delta\vec{\mathbf{d}} = \vec{\mathbf{v}}_{avg}\Delta t \approx -3.92\ \text{m/s}\ (0.800\ \text{s}) = -3.14\ \text{m}$$

Practice

Answer these questions on a separate sheet of paper, showing all work. Be sure to write your name and the lesson title on your work and keep the completed assignment in your Physics 20 binder. Keep your binder organized (i.e. assignments in the correct order) so that it will be easy to find assignments when required.

2. A car accelerates from 50.0 km/h to 80.0 km/h in 4.00 seconds. Calculate the car's acceleration. [**Important**: km/h is not the standard SI unit of velocity!]

3. A cyclist riding at 9.20 m/s accelerates at a rate of –1.20 m/s² when she applies the brakes.

   a) Explain the significance of the acceleration being negative.

   b) By rearranging the acceleration formula, calculate the time it takes for the cyclist to come to rest.

   c) Graph the cyclist's velocity versus time on graph paper.

   d) *Calculate* the cyclist's instantaneous velocity 2.00 seconds after she began braking. (Find what $\vec{\mathbf{v}}_f$ becomes when you change Δt to 2.00 s.) Is your answer in agreement with your graph?

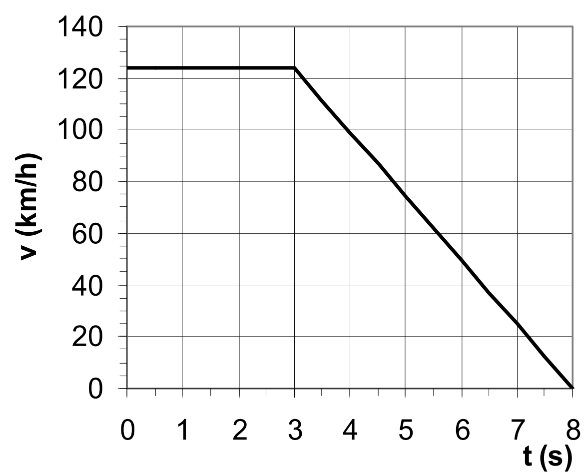
   e) Given that the cyclist accelerated uniformly from 9.20 m/s to 0.00 m/s, estimate the *average* velocity of the cyclist. Use the result to calculate her displacement while braking.

   f) Calculate the <u>*area*</u> of the triangle formed by the line on your graph and the axes. Compare this area with the displacement you calculated in (e).

4. Traffic radar recorded data for a speeding car. A graph of the data is shown below.

Motion of a Speeding Car

Velocity vs. *Time*



   a) At what time did the speeding car begin to slow down?

   b) What was the car's acceleration for the time interval *over which it was slowing*?

   c) What was the car's average acceleration for the *entire* 8.0-second time?

   d) Calculate the displacement of the car over the 8.0 seconds of the motion.

Uniform Accelerated Motion

Uniform Accelerated Motion

Motion with a constant acceleration is called **uniform accelerated motion**. (This is different from *uniform motion*, which means constant *velocity*.)

- The $\vec{\mathbf{d}}$-t graph will always have the shape of a *parabola* (the shape of $y = x^2$) for uniform accelerated motion.
- The $\vec{\mathbf{v}}$-t graph will be *linear* (constant slope) for uniform accelerated motion.
- If the $\vec{\mathbf{v}}$-t graph is not a straight line, you can "slice" the graph into separate linear sections to treat each section as UAM. Each section will have its own acceleration.
- The *area* between the $\vec{\mathbf{v}}$-t graph and the t -axis represents the displacement of the object.

Acceleration & Displacement Equations

There are *five* variables that describe uniform accelerated motion: acceleration, initial velocity, final velocity, displacement, and time interval. Time is a scalar; the others are all vectors.

There are two fundamental equations that relate the five variables:

$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i}{\Delta t} \qquad \Delta\vec{\mathbf{d}} = \frac{\vec{\mathbf{v}}_i + \vec{\mathbf{v}}_f}{2}\Delta t$$

The second equation assumes that the average velocity is the exact midpoint between the initial and velocities. This is only true if the $\vec{\mathbf{v}}$-t graph is linear, which is why the equation cannot be used when the acceleration is not constant.

Kinematics Variables

Since there are two equations, you cannot solve a UAM problem when there are more than two unknowns. You must know *three of the five variables* before solving. Here are some hints to keep in mind when it looks like you might not have enough information to solve the problem:

- If gravity is the only force causing the acceleration, you can assume $\vec{\mathbf{a}}$ = −9.81 m/s² if the motion takes place near Earth's surface.
- If the object returns to its starting point, its displacement is $\Delta\vec{\mathbf{d}} = 0$.
- At the instant where the motion changes direction (from + to −, or − to +) the velocity is $\vec{\mathbf{v}} = 0$. This applies to object's thrown straight up when they reach the highest point of the motion.

Additional Equations

If the two unknowns *both* appear in *both* equations, you will need to combine the equations in a way that eliminates one of the unknowns before solving. There are three different ways to do this, depending on which variable is eliminated.

$$v_f^2 = v_i^2 + 2\vec{\mathbf{a}} \cdot \Delta\vec{\mathbf{d}} \qquad \Delta\vec{\mathbf{d}} = \vec{\mathbf{v}}_i\Delta t + \frac{1}{2}\vec{\mathbf{a}}(\Delta t)^2 \qquad \Delta\vec{\mathbf{d}} = \vec{\mathbf{v}}_f\Delta t - \frac{1}{2}\vec{\mathbf{a}}(\Delta t)^2$$

- Proceed through the equations *in order* until you find one that contains only one unknown.
- After evaluating the first unknown, uses the simplest remaining equation to find the second unknown.
- Note that in the equation on the left, both velocities are *squared*. This means that there is no way to tell the direction of the velocities from this equation. If you use this equation to find a velocity, you must use other clues to determine whether the direction is + or −.

Example

1. A bike moving at +5.00 m/s accelerates at a rate of +2.00 m/s² over 10.0 metres. Find the bike's final velocity and the time it took to accelerate.

$\vec{\mathbf{a}}$ / (m/s²)	+2.00
$\vec{\mathbf{v}}_i$ / (m/s)	+5.00
$\vec{\mathbf{v}}_f$ / (m/s)	?
$\Delta\vec{\mathbf{d}}$ / m	+10.0
Δt / s	?

Identify the variables that are known and record them in a table. Next, choose the first of the five equations *__that only has one unknown__*. *In this case, we can find $\vec{\mathbf{v}}_f$ from:*

$$v_f^2 = v_i^2 + 2\vec{\mathbf{a}} \cdot \Delta\vec{\mathbf{d}}$$

$$\vec{\mathbf{v}}_f = \pm\sqrt{v_i^2 + 2\vec{\mathbf{a}} \cdot \Delta\vec{\mathbf{d}}}$$

$$\vec{\mathbf{v}}_f = \pm\sqrt{(5.00\ \mathrm{m/s})^2 + 2(+2.00\ \mathrm{m/s^2})\cdot(+10.0\ \mathrm{m})} = +8.06\ \mathrm{m/s}$$

Note that the equation doesn't tell us whether to use the positive or negative answer. We know that this answer must be positive because the positive acceleration means the final velocity must be larger than the initial velocity. Now choose a different equation to solve for the other unknown, Δt:

$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i}{\Delta t}$$

$$\vec{\mathbf{a}}\Delta t = \vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i$$

$$\Delta t = \frac{\vec{\mathbf{v}}_f - \vec{\mathbf{v}}_i}{\vec{\mathbf{a}}} = \frac{(+8.06\ \mathrm{m/s}) - (+5.00\ \mathrm{m/s})}{+2.00\ \mathrm{m/s^2}} = 1.53\ \mathrm{s}$$

Practice

Answer these questions on a separate sheet of paper, showing all work and sketching a $\vec{\mathbf{v}}$-t graph for each question. Be sure to write your name and the lesson title on your work and keep the completed assignment in your Physics 20 binder. Keep your binder organized (i.e. assignments in the correct order) so that it will be easy to find assignments when required.

2. During takeoff, a jet aircraft can accelerate at 3.25 m/s^2. The jet must reach a velocity of 360 km/h before it reaches the end of the runway. Find (i) the minimum time that it would take the jet to reach takeoff speed from rest, and (ii) the minimum length of runway needed.

3. A car travels 185 metres while accelerating from 60.0 km/h to 80.0 km/h. Calculate (i) the car's acceleration and (ii) the amount of time it takes to accelerate.

4. A skydiver falls 50.0 metres in 2.05 seconds, while accelerating at 6.00 m/s^2. [Remember that the directions of acceleration and displacement are negative.]

5. A ball is dropped (i.e. $\vec{\mathbf{v}}_i$ = 0) from the top of a 35.0-metre tall building. The ball accelerates downward at 9.53 m/s^2 due to the combined forces of gravity and air resistance.

6. A spacecraft travels 96.0 km in 32.0 seconds while accelerating at +20.0 m/s^2.

7. An electron moving with a velocity of +5.19 × 10^7 m/s collides with a carbon atom and slows to +2.85 × 10^6 m/s while moving 1.68 × 10^{-10} m.

8. On an alien planet, Captain Kirk falls from a 52.0-metre high cliff. He hits the ground with a velocity of −1.50 m/s.

9. A diver jumps from a 10.0 m platform with an initial upward velocity of 2.40 m/s.

   a) How long does it take for the diver to reach the highest point of his trajectory? How high above the water is the diver at this highest point?

   b) How long does it take for the diver to reach the water? What is his velocity at this point?

10. A research rocket is launched straight up, starting from rest. The researchers want the rocket to reach an altitude of 12.0 km within 30.0 seconds of launch. Find the acceleration and final velocity. You may **not** assume that the acceleration is $\vec{\mathbf{a}}$ = −9.81 m/s^2 while the rocket engine is firing!

11. a) A ball is kicked straight up from ground level with a velocity of +21.0 m/s. How long does the ball take to reach its highest point? How high does the ball rise before it starts to fall back to the ground?

    b) Calculate the hang time for the ball.

12. The driver of a car sees that a bridge 285 m ahead is washed out. The driver immediately hits the brakes, causing the car to accelerate at −2.50 m/s^2. If the car just barely stops in time, what was its initial velocity?

13. ⚡ The driver of the car in the previous question has a *"reaction time"* of 0.650 seconds. This means that the car will continue to move at its initial velocity for 0.650 seconds before the brakes are applied. Using this new information, calculate the acceleration and stopping time required for the driver to avoid an accident.

14. ⚡ A toy rocket is launched upward from rest. The rocket has enough fuel to accelerate at +25.0 m/s^2 for 4.25 seconds. After the fuel runs out, the rocket's acceleration (neglecting air resistance) will be 9.81 m/s^2 in the downward direction. Determine the (i) maximum height, (ii) maximum velocity, and (iii) total hang time of the rocket.

Name: ____________________

MOTION OF A ROLLING BALL

Introduction

A "Calculator-Based Ranger" (CBR) is a sonar device that sends out clicking sounds and determines the distance to the nearest obstacle based on how long it takes the echoes to return.

The CBR connects to a computer or a calculator. A program is used to control the CBR and retrieve the data it collects. You will need to program the CBR to take 20 measurements at intervals of 0.050 seconds.

Data Collection: Horizontal

1. Place the CBR on a level floor. Position the basketball 50 cm in front of the CBR in the direction that its speaker is pointing. If the ball is closer than 50 cm to the CBR the distance measurements will not be reliable. Ensure that there are no obstructions such as walls, furniture, or people in front of the CBR; the basketball must be the only object from which the sound waves can echo.
2. Roll the ball directly away from the CBR. Start the CBR data collection when the ball begins moving. After the CBR data transfers to the calculator, record the position data from "L4" in the middle column of the table below for 11 consecutive points. Do not include any points collected before the ball begins moving. It does not matter if the *Time* values do not match, as long as the *interval between* the times is 0.050 seconds.

Data Collection: Incline

3. Repeat the data collection for the basketball rolling down an incline (such as a long table that has been propped up at one end.) You do not need to push the basketball; just release it. Ensure that the ball starts at least 50 cm from the CBR as before. Record the data in the final column.

Time t / s	Horizontal Position $\vec{\mathbf{d}}$ / m	Incline Position $\vec{\mathbf{d}}$ / m
0.000		
0.050		
0.100		
0.150		
0.200		
0.250		
0.300		
0.350		
0.400		
0.450		
0.500		

Data Analysis

4. Create one scatter plot for the *Horizontal* data on a second scatter plot for the *Incline* data. Graph paper is provided on the last page of this handout. Choose the axis scales so that the data points use as much of the graph paper as possible. Add a best-fit line *only* if the data produces a straight line.

5. Qualitatively, describe how the two graphs differ. Classify each of the two graphs as either *uniform* or *accelerated* motion.

6. a) Calculate the *slope* of the best-fit line for graph of the *Horizontal* data. Show all work.

   b) What is the significance of this slope?

7. a) Calculate the *average* velocity of the basketball for the *Incline* data. Show all work.

   b) Explain the difference between the *average* velocity and the *instantaneous* velocity. Why is this distinction more important for the incline than for the horizontal surface?

Extension

8. a) Open the Desmos Graphing Calculator at https://www.desmos.com/calculator/nbwubldj26. Edit the data table to display your data for the *Incline* motion. The calculator will try to draw a parabola-shaped curve to fit the data. Print the graph and attach it to this report.

   b) How well does the parabolic curve fit your data?

Name: ____________________________

MOTION OF A BOUNCING BALL

Introduction

In this activity, we will mount the CBR to the centre of a door frame, pointing down so that it can collect data for a *bouncing* basketball.

Data Collection

1. Program the CBR to collect 60 data points at intervals of 0.050 seconds. Hold the basketball 50 cm below the CBR, start the data collection and release the ball. Ensure that there are no obstructions (including yourself and the calculator cable) near the CBR.
2. Transcribe the data from "L4" of your calculator into the table below. Do not record any data points before the ball starts moving. It does not matter if the *Time* values do not match, as long as the *interval between* the times is 0.050 seconds.

Time t / s	Position $\vec{\mathbf{d}}$ / m
0.000	
0.050	
0.100	
0.150	
0.200	
0.250	
0.300	
0.350	
0.400	
0.450	
0.500	
0.550	
0.600	
0.650	
0.700	

Time t / s	Position $\vec{\mathbf{d}}$ / m
0.750	
0.800	
0.850	
0.900	
0.950	
1.000	
1.050	
1.100	
1.150	
1.200	
1.250	
1.300	
1.350	
1.400	
1.450	

Data Analysis

3. Create a scatter plot for your data.
4. a) Using the first two data points (i.e. between t_1 = 0.000 s and t_2 = 0.050 s) calculate the initial velocity of the basketball. Show your work.

   b) Record your velocity in the table on the next page. Use the midpoint between the two times (i.e. t = 0.025 s) for the time.

   c) Repeat your velocity calculations for all consecutive pairs of points. For example, calculate the velocity between 0.050 and 0.100 seconds and use this as the velocity at the midpoint, 0.075 s. You do not have to show your calculations.

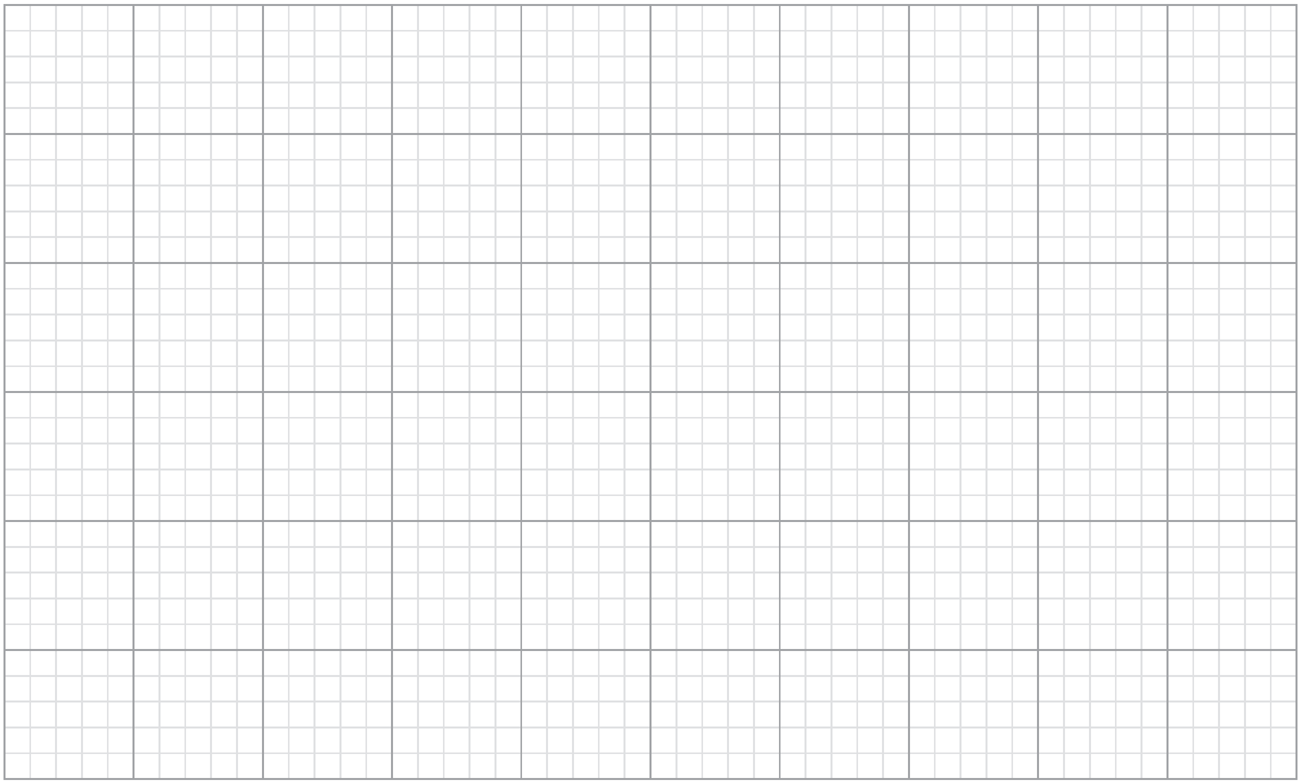
Time t / s	Velocity $\vec{\mathbf{v}}$ / (m/s)
0.025	
0.075	
0.125	
0.175	
0.225	
0.275	
0.325	
0.375	
0.425	
0.475	
0.525	
0.575	
0.625	
0.675	
0.725	

Time t / s	Velocity $\vec{\mathbf{v}}$ / (m/s)
0.775	
0.825	
0.875	
0.925	
0.975	
1.025	
1.075	
1.125	
1.175	
1.225	
1.275	
1.325	
1.375	
1.425	

5. Make a scatter plot of your velocity versus time data.
6. Describe the appearance of your graph and explain why it looks the way it does.

7. Add a best-fit line to the *longest, linear section* of the graph. Calculate the slope of this line segment. Show your work.

8. Qualitatively compare the slopes of the other segments to this one and explain why the data looks like this.



Displacement Name: ______________________________

Question 2a

Question 2c

Question 3

Question 4

Question 2

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 3

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 4

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 5

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 6

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 7

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 8

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 9

	Up Only	Up & Down
$\vec{\mathbf{a}}$ / (m/s^2)		
$\vec{\mathbf{v}}_i$ / (m/s)		
$\vec{\mathbf{v}}_f$ / (m/s)		
$\Delta\vec{\mathbf{d}}$ / m		
Δt / s		

Question 10

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 11

	Up Only	Up & Down
$\vec{\mathbf{a}}$ / (m/s^2)		
$\vec{\mathbf{v}}_i$ / (m/s)		
$\vec{\mathbf{v}}_f$ / (m/s)		
$\Delta\vec{\mathbf{d}}$ / m		
Δt / s		

Question 12

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 13

$\vec{\mathbf{a}}$ / (m/s^2)	
$\vec{\mathbf{v}}_i$ / (m/s)	
$\vec{\mathbf{v}}_f$ / (m/s)	
$\Delta\vec{\mathbf{d}}$ / m	
Δt / s	

Question 14

	Fuel	No Fuel (Up Only)	No Fuel (Up & Down)
$\vec{\mathbf{a}}$ / (m/s^2)	+25.0	−9.81	−9.81
$\vec{\mathbf{v}}_i$ / (m/s)	0.00		
$\vec{\mathbf{v}}_f$ / (m/s)			
$\Delta\vec{\mathbf{d}}$ / m			
Δt / s	4.25		