AP Physics course # 880 is open to students enrolled in BC Calculus (or those who have taken the course in the past). A solid understanding of the following topics in Mathematics is implicitly assumed:

- Graphing of functions – including but not limited to linear, quadratic, exponential, logarithmic and trigonometric functions
- Interpreting graphs and data
- 2D Vectors – including but not limited to being able to translate between \((A_x, A_y)\) representation, \(A_x\hat{i} + A_y\hat{j}\) representation and \((|A|, \theta)\) representation, addition and subtraction of vectors, dot and cross products of vectors
- Basic differential calculus - limited to being able to take derivatives of functions of form \(f(x) = Ax^n\) as well as the geometric interpretation of derivative as the slope of the function
- Basic integral calculus - limited to being able to take anti-derivative of functions of form \(f(x) = Ax^n\) as well as the geometric interpretation of integral as the area under the curve of the function

This assignment covers parts of the first few chapters of the assigned textbook, which will be checked out to you for the summer.

TEXTBOOK: *Physics for Scientists and Engineers* Second Edition, Randall D. Knight

Please **read** the chapters when you are working on the assignment. Don't skim it, don't look ahead at the problems you need to solve and see whether you can do them.

Read each chapter carefully – think about the reasons why the concepts are being introduced and how they fit it with your prior understanding. **KNOW YOUR DEFINITIONS.** You should be able to explain in words what equations might be capturing mathematically.

The textbook has some helpful strategies for effective reading:

- Check your understanding with the Stop to Think questions
- Examples (with light purple background); Tactics Boxes (step-by-step how-to’s with light pink backgrounds); Problem-solving Strategy boxes (also pink) and Notes (with the word NOTE in red) help build a solid understanding of the concepts
Please remember:

1. The H.W is due the second day of school – the H.W counts for a grade.
2. I need the SOLUTIONS to the problems! I should be able to see clearly HOW you arrived at the answer.
3. Some questions ask you to WRITE OUT your thinking – this may seem silly in the beginning but when you graduate to solving multi-step, multi-concept problems, being able to chart a pathway towards the final solution will be invaluable.
4. DO NOT LEAVE THIS ASSIGNMENT TO THE LAST MINUTE. That will defeat the real purpose of this assignment.

**Additional Resources:** Bookmark these and use them all year.

1. This following resource is great for step-by-step problem solving. All topics in AP Physics C (Mechanics and Electricity & Magnetism are covered).

2. This following resource has video lectures and multiple-choice questions with answers (and the logic for the answers explained very well)

3. AK LECTURES is an online educational platform focused around providing you with clear and concise explanations to difficult concepts. This site is great if you want to review specific topics in Physics.

4. iLecture Online is a great spot to go to review specific AP style problems. Just about every type of problem is broken down and solved piece by piece.
   [http://www.ilectureonline.com/lectures/subject/PHYSICS](http://www.ilectureonline.com/lectures/subject/PHYSICS)

5. Hyperphysics is a physics concept map based website designed by Georgia State University. Here you will find excellent graphics and a nice overview of concepts.
   [http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html](http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html)

Please feel free to contact me anytime during the summer with questions or comments.

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PART A: Math Skill by Topic:
ALGEBRA

1. \( x^2 + 40 = 13x \) Find the value(s) of \( x \) that solve the equation

\[
y_1 = 5 + 5x - x^2
\]

2. \( y_2 = 10 + 10x \) Find the value(s) of \( x \) that solve the equations.
\[
y_2 = y_1 + 10
\]

3. \( 2x + 3y = 2 \) Find the value of \( x \) and \( y \) that solves the simultaneous equations.
\[
x + 4 = y - 2
\]

4. \( 40 - x = 4z \) Find the value of \( x, y, z \) and \( t \) that solves the simultaneous equations.
\[
y - 20 = 2z \quad x - y = 0.2 \quad t
0.1 \ t = z
\]

5. \( \ln(x) - \ln(10) = -\frac{0.25}{2} \ t \) Using logarithmic identities, write \( x \) as a function of \( t \), i.e., in the form \( x = f(t) \)
TRIGONOMETRY and VECTORS

6. For the right triangle shown on the right, find the missing side and all the angles.

7. For the triangle shown on the right, find the missing side and the angles.

8 (a). Add the vectors graphically (you may use a ruler):

8 (b). Subtract the vectors graphically (you may use a ruler):

9. A boat is sailing due east at 5 m/s. The wind is blowing out of southwest at 6 m/s, i.e., blowing towards northeast at an angle of 40° (40° north of east). The wind changes the boat’s velocity so that the new velocity of the boat is the vector sum of 5m/s due east and 6m/s, 40° north of east. Find the magnitude and direction of the boat’s new velocity. Use analytical methods only, i.e., no graphical methods.

Please review dot product and cross product of vectors.

10 (a). Find $A \cdot B$

10 (b) Find $A \times B$
Recall the last chapter from your Precalculus class specifically:\n\[ \frac{d}{dx} x^n = nx^{n-1} \]

11. \( v(t) = \frac{dx}{dt} \); \( x(t) = -5t^2 + 10t + 5 \) Find \( v(t) \). At what time is \( v(t) = 0? \)

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**Part B  Skill: Reading GRAPHS**

**Reading Position-time graphs:** position along y and time along x axis
- straight line parallel to time axis = object standing still
- sloped straight line = constant velocity
- curved line = object accelerating
- slope gives velocity – if slope is positive, velocity is positive and vice versa. Steeper slope = greater speed.
- Curve that looks like an upward facing parabola (or part of an upward facing parabola) = positive acceleration; Curve that looks like a downward facing parabola (or part of a downward facing parabola) = positive acceleration
- REMEMBER: positive acceleration DOES NOT always mean speeding up. It only means that the velocity is increasing and velocity being a vector quantity has direction (sign). Initial Velocity of -3 m/s is smaller than final velocity of -1 m/s however initial speed of 3 m/s is greater than the final speed of 1 m/s. In this case the acceleration is + while the object slows down.
- SIMPLE RULE: Object speeds up if both velocity and acceleration have same sign - both + or both – Object slows down if velocity and acceleration have opposite signs

**Reading Velocity-time graphs:** velocity along y and time along x axis
- straight line parallel to time axis = object moving at constant velocity; velocity positive if graph in 1st quadrant – velocity negative if graph in 4th quadrant
- sloped straight line = constant acceleration
- curved line = acceleration changing
- slope gives acceleration – if slope is positive, acceleration is positive and vice versa. Steeper slope = greater magnitude of acceleration.
- REMEMBER THE SIMPLE RULE: Object speeds up if both velocity and acceleration have same sign - both + or both – Object slows down if velocity and acceleration have opposite signs
Practice: Reading Graphs

Part I: Answer the following AP Multiple-choice questions:

1. Which of the following graphs of position $d$ versus time $t$ corresponds to motion of an object in a straight line with positive acceleration?
   - (A) 
     \[
     \begin{array}{c}
     \text{(A) } \\
     \text{O} \\
     \text{O} \\
     t
     \end{array}
     \]
   - (B) 
     \[
     \begin{array}{c}
     \text{(B) } \\
     \text{O} \\
     \text{O} \\
     t
     \end{array}
     \]
   - (C) 
     \[
     \begin{array}{c}
     \text{(C) } \\
     \text{O} \\
     \text{O} \\
     t
     \end{array}
     \]
   - (D) 
     \[
     \begin{array}{c}
     \text{(D) } \\
     \text{O} \\
     \text{O} \\
     t
     \end{array}
     \]
   - (E) 
     \[
     \begin{array}{c}
     \text{(E) } \\
     \text{O} \\
     \text{O} \\
     t
     \end{array}
     \]

2. A ball is thrown straight up from a point 2 m above the ground. The ball reaches a maximum height of 3 m above its starting point and then falls 5 m to the ground. When the ball strikes the ground, what is its displacement from its starting point?
   - (A) Zero
   - (B) 8 m below
   - (C) 5 m below
   - (D) 2 m below
   - (E) 3 m above

3. What do acceleration and velocity have in common?
   - (A) Both are scalars.
   - (B) Both are vectors.
   - (C) Both are measured in units of distance divided by time.
   - (D) Both are measured in units of distance divided by time squared.
   - (E) They are different names for the same quantity.
The graph above shows velocity $v$ versus time $t$ for an object in linear motion. Which of the following is a possible graph of position $x$ versus time $t$ for this object?

(A)  
(B)  
(C)  
(D)  
(E)  

2. The graph above shows velocity versus time for an object moving in a straight line, initially in the $+x$ direction. Which of the following is true for the motion of the object for the entire time shown on the graph?

(A) Its speed decreases with constant acceleration.
(B) Its speed increases with constant acceleration.
(C) Its speed decreases with acceleration that also decreases in magnitude.
(D) Its speed decreases to zero, then increases as the object moves in the $-x$ direction.
(E) Its acceleration decreases at a constant rate to zero, then increases at a constant rate.

Which of the following pairs of graphs shows the distance traveled versus time and the speed versus time for an object uniformly accelerated from rest?

(A)  
(B)  
(C)  
(D)  
(E)
At time $t = 0$, car X traveling with speed $v_0$ passes car Y, which is just starting to move. Both cars then travel on two parallel lanes of the same straight road. The graphs of speed $v$ versus time $t$ for both cars are shown above.

4. Which of the following is true at time $t = 20$ seconds?
   (A) Car Y is behind car X.  (B) Car Y is passing car X.  (C) Car Y is in front of car X.
   (D) Both cars have the same acceleration.  (E) Car X is accelerating faster than car Y.

5. From time $t = 0$ to time $t = 40$ seconds, the areas under both curves are equal. Therefore, which of the following is true at time $t = 40$ seconds?
   (A) Car Y is behind car X.  (B) Car Y is passing car X.  (C) Car Y is in front of car X.
   (D) Both cars have the same acceleration.  (E) Car X is accelerating faster than car Y.
An object is shot vertically upward into the air with a positive initial velocity. Which of the following correctly describes the velocity and acceleration of the object at its maximum elevation?

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>(B) Zero</td>
<td>Zero</td>
</tr>
<tr>
<td>(C) Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>(D) Zero</td>
<td>Negative</td>
</tr>
<tr>
<td>(E) Positive</td>
<td>Negative</td>
</tr>
</tbody>
</table>

In a classroom demonstration, a teacher has a coin and feather in a long tube. The teacher uses a vacuum pump to remove all the air from the tube. The feather and coin are then dropped from the top of the tube at the same time. Which of the following describes what happens and why?

(A) The coin hits the bottom of the tube first because it weighs more.
(B) The coin hits the bottom of the tube first because it is more dense.
(C) The feather hits the bottom of the tube first because it weighs less.
(D) The coin and feather hit the bottom of the tube at the same time because they weigh the same.
(E) The coin and feather hit the bottom of the tube at the same time because they have the same acceleration.

The following is the velocity-time graph of an object during a 5 second interval:

Which sentence is the best interpretation of the velocity-time graph shown above?

(A) The object is moving with a constant acceleration.
(B) The object is moving with a uniformly decreasing acceleration.
(C) The object is moving with a uniformly increasing velocity.
(D) The object is moving with a constant velocity.
(E) The object does not move.

The following is the velocity-time graph of an object during a 5 second interval:

Which of the following graphs of acceleration versus time would best represent the object’s motion during the same time interval?
Part II: Reading a velocity-time graph

Look at the Following Velocity-time graph for an object moving along the x-axis. Object starts at rest at time t=0. Successive vertical lines are separated by 1 s and successive horizontal lines are separated by 1 m/s. Round values to the nearest whole number.

Sign convention: Forward is +ve; Backward is -ve

Answer the questions that follow the graph. Do not use Kinematic equations to answer Q.1 - Q.25.

REMEMBER to REMIND yourself BEFORE you read each question that this is a VELOCITY-TIME graph!! Refer to the graph often.
1. During which time duration(s) is the object traveling forward?

2. During which time duration(s) is the object traveling backward?

3. During which time duration(s) does the object have positive acceleration?

4. During which time duration(s) does the object have negative acceleration?

5. What is the maximum velocity attained by the object?

6. What is the minimum speed attained by the object?

7. At which instant(s) does the object have greatest velocity?

8. During which time duration(s) is the object speeding up?

9. During which time duration(s) is the object slowing down?

10. At which instant is the object farthest from the origin?

11. During which time duration(s) is the object traveling towards the origin?

12. During which time duration(s)s does the object have greatest positive acceleration?

13. During which time duration(s)s does the object have greatest negative acceleration?

14. What is the value of the greatest positive acceleration?

15. What is the value of the greatest negative acceleration?

16. How far does the object travel while moving forward before it first stops momentarily (after it stated moving)?
17. How much of distance found in Q.16. is covered by the particle with a positive acceleration?

18. How much of distance found in Q.16. is covered by the particle with a negative acceleration?

19. Describe the movement of the particle during the rest of the distance found in Q.16.?

20. How much distance is traveled by the particle while moving backward?

21. How far is the particle from the origin before it comes to a stop (momentarily) for the second time (after it started moving)?

22. What total distance is traveled by the particle between t=0 and when it comes to a stop for the second time?

23. What total distance is traveled by the particle between the start of journey and end of journey (when the graph ends)?

24. How far is the particle from the origin when it comes to a stop at the end of journey (when the graph ends)?

25. What is the average speed of the particle during the entire journey?
Part C  Skill: Graphing Data

When data is collected that looks at the effect of changing one variable on another, graphing becomes a useful tool for visualizing the dependence.

Often computer modeling can predict the values for the constants a, m, c, m etc., but sometimes one has to figure out these values analytically.

In case (a) the value for m can be found by finding the slope and b is the y-intercept.

In (c), however, finding the constant a becomes tricky as there is no straight line!

If you can manipulate the raw data so as to plot a straight line, then taking the slope of the best-fit straight line gives you the most accurate method for finding the constants in a reliable way.

So, how can we get a straight line for (c) above?

Let's assume the data table for (c) above is:

<table>
<thead>
<tr>
<th>x</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>10</td>
<td>5</td>
<td>2.5</td>
<td>8</td>
</tr>
</tbody>
</table>

\[
y = \frac{a}{x}; \quad \text{Let us define a new variable } z = \frac{1}{x}; \quad \text{Then}
\]

\[
y = az \quad \text{is the equation for a straight line!}
\]

If we plot y vs z instead of y vs x, we will get straight line!!

Now fill in values for z in the table on the right and plot \( y \text{ vs } z \) below.

Also calculate the value of a by taking the slope of the line!!

\[
\text{In (b) above, unless } b = 0 \text{ or } c = 0, \text{ we cannot get a straight line by a simple transformation! When } b = 0, \text{ we can define } z = x^2 \text{ and get}
\]

\[
y = az + c, \text{ a straight line!!}
\]

\[
\text{In (d) above, } y = a^z. \text{ Taking natural log on both sides gives}
\]

\[
\log y = x \log a. \text{ Plotting } \log y \text{ vs. } x \text{ will give you a straight line whose slope is } \log a, \text{ from which } a \text{ can be calculated!!}
\]
**Applying Graphing Skill # 1:**

Newton's second Law states that $F_{\text{NET}} = ma$. The acceleration of an object is directly proportional to the net applied force; the net Force is the vector sum of all the forces.

Consider the scenario below: a cart is being pulled to the right. The force sensor measures the applied force $F$ (the force in the string) and the motion sensor measures the acceleration $a$.

Friction points to the left, so $F_{\text{NET}} = ma$ becomes: $F - F_{\text{Fric}} = ma$. $F$ & $a$ are variables; $m$ & $F_{\text{fric}}$ constants.

A student pulls the force sensor with a constant force, and the cart accelerates. This is repeated for several trials, with a different constant force used for each trial. The data are recorded in the table below.

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force sensor reading (N)</td>
<td>0.32</td>
<td>0.38</td>
<td>0.44</td>
<td>0.50</td>
<td>0.60</td>
</tr>
</tbody>
</table>

(b)  

i. On the grid below, plot data points for the acceleration of the cart as a function of the force sensor reading. Clearly scale all axes. Draw a straight line that best represents the data.

ii. Using the straight line from the graph, calculate the mass of the cart.

iii. Using the straight line from the graph, determine the magnitude of the force of friction.
Applying Graphing Skill # 2:

When allowed to fall, the hanging block of mass \( m \) (see diagram on the right) descends with a constant acceleration and the pulley turns counterclockwise. The acceleration depends on \( m \) and the shape of the pulley. We will learn to analyze this system in detail later in the course.

The hanging block starts from rest so \( v_0 = 0 \).

\[
x = D = \frac{1}{2} at^2
\]

The time \( t \) is measured for various heights \( D \) and the data are recorded in the following table.

<table>
<thead>
<tr>
<th>( D ) (m)</th>
<th>( t ) (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.68</td>
</tr>
<tr>
<td>1</td>
<td>1.02</td>
</tr>
<tr>
<td>1.5</td>
<td>1.19</td>
</tr>
<tr>
<td>2</td>
<td>1.38</td>
</tr>
</tbody>
</table>

i. What quantities should be graphed in order to best determine the acceleration of the block? Explain your reasoning.

ii. On the grid below, plot the quantities determined in (b)i., label the axes, and draw the best-fit line to the data.

iii. Use your graph to calculate the magnitude of the acceleration.
Part D  
Skill: Problem Solving

\[ v = v_0 + at \]  \hspace{1cm} Eq.1

\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]  \hspace{1cm} Eq.2

\[ v^2 = v_0^2 + 2a(x - x_0) \]  \hspace{1cm} Eq.3

Identify the symbols in the three equations above:

\[ x \ldots \ldots \]
\[ x_0 \ldots \ldots \]
\[ x - x_0 \ldots \ldots \]
\[ v_0 \ldots \ldots \]
\[ v \ldots \ldots \]
\[ t \ldots \ldots \]
\[ a \ldots \ldots \]

1. What are vector quantities? Which of the above quantities are vectors?

2. (a) Can an object (point particle) traveling in the positive direction have a negative acceleration? Give an example if your answer is yes.

(b) What happens to the \textbf{instantaneous speed} of a point particle if it has the following signs for velocity and acceleration? Give both the ‘short time horizon’, i.e., immediately afterwards, and the ‘long time horizon’, i.e., after sufficient time has elapsed, answers. Your answers will state ‘speeding up’, ‘slowing down’ etc.

(i) velocity (-) and acceleration (+)

(ii) velocity (-) and acceleration (-)

(iii) velocity (+) and acceleration (+)
SOLVE THE FOLLOWING PROBLEMS SHOWING ALL STEPS – an answer shouldn't 'magically' appear in the space provided below. Mention which equation was used to arrive at the answer

Vector quantities require a coordinate system with a positive and negative sense of direction in order to describe them. We will use right (positive), left (negative), up (positive) and down (negative) sign convention. The zero of the coordinate system is entirely arbitrary.

3. A motorcycle is moving at 30 m/s when the rider applies the brakes, giving the motorcycle a constant negative acceleration. During the 3.0s interval immediately after braking begins, the speed decreases uniformly to 15 m/s.
   (a) What is the acceleration of the motorcycle?

   (b) How long does the motorcycle take to come to rest after braking begins?

   (c) What distance does the motorcycle travel from the instant braking begins until it comes to rest?

4. The driver of a car slams on the brakes when he sees a tree blocking the road. The car slows down uniformly with an acceleration of \(-5.60\) m/s\(^2\) for 4.20 s, making straight skid marks 62.4 m long ending at the tree.
   (a) What is the speed of the car when the driver slams on the brakes?

   (b) What is the speed of the car when it crashes into the tree?

5. At the instant the traffic light turns green at an intersection, a car starts from rest with a constant acceleration of 2.2 m/s\(^2\). At the same instant, a truck, traveling with a constant speed of 9.5 m/s, overtakes and passes the automobile.
   (a) Taking \(t = 0\) at the instant the truck passes the car, at what later time does the car overtake the truck? (Hint: objects catch up or overtake when they have the same final position at the same instant)

   (b) How far beyond the traffic signal will the car overtake the truck?

   (c) How fast will the car be traveling at that instant?
(d) Draw position time graphs qualitatively for the car (solid line) and the truck (dotted line) on the same graph and identify the point found in (a)

(e) Now suppose that while all the quantities are the same for the car and the truck, the car takes off from the intersection 1 second after the truck leaves. When does the car catch up with the truck?

6. A Porsche challenges a Honda to a 400 m race on a straight track. Since the Porsche’s acceleration of 3.5 m/s$^2$ is greater than the Honda’s 3.0 m/s$^2$, the Honda gets a 50 m head start. Both cars start accelerating at the same instant. Who wins?

7. A train is moving towards a destroyed bridge. The velocity of the train remains constant at 20 m/s. A person inside the train realizes that he will die unless he runs to the back of the train and jumps out. If the person is 15 m from the back of the train and the back of the train is 50 m from the break in the track, with what velocity must the person run with respect to the ground to make it to the back of the train just as the back of the train goes over the break in the bridge?
8. A car accelerates at 2.0 m/s\(^2\). It passes two marks 30.0 m apart at times \(t = 4.0\) s and \(t = 5.0\) s. What was the car’s initial velocity (velocity at \(t = 0.0\) s)?

[21 m/s]

ACCELERATION DUE TO GRAVITY is taken to be 10 m/s\(^2\) DOWNWARDS. Remember, acceleration is a vector! So, \(\vec{a} \text{ due to gravity} = -10\text{m/s}^2\).

9. Rumor has it, that upon the building’s completion, a certain physics faculty member contributed significantly to our understanding of gravitation and its effects on large fruit by dropping a watermelon off Wheeler House’s top floor. Given that it took 1.414 seconds before it impacted the floor, from how far off the ground was it dropped?

10. A cannonball is shot straight up from the ground with an initial velocity of 100 m/s.
   (a) How high does it go? (Hint: what is its speed at the highest point?)
   (b) How long does it take to reach the highest point?
   (c) What is its velocity as it reaches the ground? (Hint: what is the displacement of the cannonball when it reaches the ground?)
   (d) How long does it take to travel the first 50 m while going up?
   (e) What is its velocity at the end of the first 50m?
   (f) How long does it take to travel the next 50 m?
11. Heather and Jerry are standing on a bridge 50 m above a river. Heather throws a rock straight down with a speed of 20.0 m/s and Jerry, at the exact moment, throws a rock straight up with a speed of 20.0 m/s.

(a) At what time after leaving Heather’s hand does the rock hit the water?

(b) At what time after leaving Jerry’s hand does the rock hit the water?

(c) What is the velocity of the rock that Heather threw right before it hits the water?

(d) What is the velocity of the rock that Jerry threw right before it hits the water?

(e) How do you explain the answers to (c) and (d) above?

12. A small rocket, such as those used for meteorological measurements, is launched vertically with an acceleration of 30 m/s². It runs out of fuel after 30 seconds.

(a) What is the rocket’s velocity at 30 seconds?

(b) What is the rocket’s height above ground at 30 s?

(c) What is the rocket’s acceleration after 30 s?

(d) How high does the rocket reach (from its launch point) after its fuel runs out?

(e) With what velocity does the rocket return to the ground?
13. A ball is dropped from a height of 5.0 m above the ground. After hitting the ground, it rebounds with the same speed it had just before hitting the ground. At the instant that the ball rebounds, a small blob of clay is dropped from the same 5.0 m height, directly above the ball.

(a) What is the speed of the ball just before it strikes the ground?

(b) At what time after the clay blob is released, do the two objects collide?

(c) What is the height above the ground where the collision takes place?

(d) What is the velocity of the ball just before collision?

(e) What is the velocity of the clay blob just before the collision?
Part E
Skill: Manipulating Equations with Symbols

\[ v = v_0 + at \quad \text{Eq.1} \]
\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \quad \text{Eq.2} \]
\[ v^2 = v_0^2 + 2a(x - x_0) \quad \text{Eq.3} \]

Example: A car and a delivery truck both start from rest and accelerate at the same rate. However, the car accelerates for twice the amount of time as the truck. What is the final speed of the car compared to the truck?
A. Half as much
B. The same
C. Twice as much
D. Four times as much
E. One quarter as much

Solution:

<table>
<thead>
<tr>
<th>CAR</th>
<th>TRUCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v_0 = 0 )</td>
<td>( v_0 = 0 )</td>
</tr>
<tr>
<td>( a_C = a )</td>
<td>( a_T = a )</td>
</tr>
<tr>
<td>( t_C = 2T )</td>
<td>( t_T = T )</td>
</tr>
<tr>
<td>( v_C = a(2T) )</td>
<td>( v_T = a(T) )</td>
</tr>
</tbody>
</table>

Strategy that always works: DIVIDE the equations!!
\[ \frac{v_C}{v_T} = \frac{a(2T)}{a(T)} = 2 \]
C. is the correct answer!!!

1. A modern car can develop an acceleration four times greater than an antique car like "Lanchester 1800". If they accelerate over the same distance, what would be the velocity of the modern car compared to the antique car?
   A. Half as much
   B. The same
   C. Twice as much
   D. Four times as much
   E. One quarter as much
2. A package is dropped from an air balloon two times. In the first trial the distance between the balloon and the surface is \( H \) and in the second trial \( 4H \). Compare the time it takes for the package to reach the surface in the second trial to that in the first trial?

A. The time in the second trial is four times greater  
B. The time in the second trial is two times greater  
C. The time the same in both trials because it doesn’t depend on height  
D. The time in the second trial is four times less  
E. The time in the second trial is two times less

3. An archer practicing with an arrow bow shoots an arrow straight up two times. The first time the initial speed is \( v_0 \) and second time he increases the initial speed to \( 4v_0 \). How would you compare the maximum height in the second trial to that in the first trial?

A. Two times greater  
B. Four times greater  
C. Eight times greater  
D. Sixteen times greater  
E. The same

4. Derive equation # 3 from Equations 1 and 2!
Part F  Calculus based problems:

1. \( x(t) = 2.67 - 8t + 3.8t^2 - 0.5t^3 + 0.02t^4 \)

(a) Calculate the position at \( t = 2 \) s; position is given in m.
(b) Calculate the instantaneous velocity at \( t = 2 \) s.
(c) Calculate the instantaneous acceleration at \( t = 2 \) s.
(d) Calculate the average velocity between \( t = 0 \) s and \( t = 2 \) s.

2. A particle moving along the \( x \) axis has its position described by the function \( x = (2t^2 - t + 1) \) m where \( t \) is in seconds. At \( t = 2 \) s, what is the particle’s (a) position, (b) velocity and (c) acceleration.

The figure below shows the acceleration-versus-time graph of a particle moving along the \( x \)-axis. Its initial velocity is \(-4 \) m/s at \( t = 0 \) s and it was located at the origin at that time.

(a) What is the velocity at \( t = 2 \) s and \( t = 4 \) s.
(b) Write velocity as a function of time.
(c) At what time is the velocity zero?
(d) What is the velocity at the instant the acceleration is zero? What is the significance of this value?
Part G  2-Dimensional Kinematics - Projectiles
Read Chapter 3 to brush up on vectors.  Read sections 4.1-4.3.

1. A projectile is launched with an initial speed of 30m/s at an angle of 60° above the horizontal. Calculate the magnitude and direction of its velocity as well as the horizontal and vertical displacements 5.0s after launch?

2. An object is launched from the ground into the air at an angle of 38.0° (above the horizon) towards a vertical brick wall that is 15.0 m horizontally from the launch point. If the ball takes 1.30 seconds to collide with the wall, with what speed was the ball launched?

3. A ball is tossed into the air at a speed of 64.0 m/s at an unknown angle. If the ball is observed to rise to a maximum height of 7.80 m, at what angle was the ball thrown relative to the ground?

4. A rock is launched from the ground into the air. After 1.40 seconds the rock is observed to have a speed of 22.0 m/s at an angle +18.0° above horizontal. Neglecting air resistance, with what speed was the rock launched?
5. A rifle is aimed horizontally at a target 50m away. The bullet hits the target 2.0cm below the target point. (a) What was the bullet’s flight time? (b) What was the bullet’s speed as it left the barrel? Note units.

6. A projectile is fired with an initial speed of 30m/s at an angle of 60° above the horizontal. The object hits the ground 7.5 s later.
   (a) How much higher or lower is the launch point relative to the point where the projectile hits the ground?
   (b) To what max. height above the launch point does the projectile rise?
   (c) What are the magnitude and direction of the projectile’s velocity at the instant it hits the ground?

7. The figure below shows three identical projectiles launched from the ground with identical speeds and angles. The projectiles do not land on the same terrain. Rank the situations according to the final speeds of the projectiles just before they land, greatest first. Give reasons.

8. A ball is projected downward at an angle of 30° with the horizontal from the top of a building 170 m high. Its initial speed is 40m/s. (a) How long will it take before striking the ground? (b) How far from the foot of the building will it strike? (c) At what angle with the horizontal will it strike?
   (4.2s; 150m; 60°)
9. You are 6.0 m from one wall of a house. You want to toss a ball to your friend who is 6.0 m from the opposite wall. The throw and catch occur 1.0 m above the ground. (Refer to fig. P4.49 on p.123 of your textbook) (a) What min. speed will allow the ball to clear the roof? (b) At what angle will you toss the ball?

10. A baseball is thrown toward a player with an initial speed of 20 m/s at an angle of 45° with the horizontal. At the moment the ball is thrown, the player is 50 m from the thrower. At what speed and in what direction must he run to catch the ball at the same height at which it was released? (3.2 m/s)

11. A certain airplane has a speed of 80 m/s and is diving at an angle 30.0° below the horizontal when a radar decoy is released. The horizontal distance between the point where the decoy is released and the point where the decoy strikes the ground is 690 m. (a) How high was the plane when the decoy was released? (b) How long was the decoy in air? (The decoy has the same velocity as the airplane at the instant it is released)
12. A gun shoots bullets that leave the muzzle at 250 m/s. If a bullet is to hit a target 100 m away at the level of the muzzle, the gun must be aimed at a point above the target. How far above the target is this point? (78.5 cm)  
(Recall Trig Identity: $2 \sin \theta \cos \theta = \sin 2\theta$)

13. A baseball player hits a baseball that lands in the stands 24 m above the playing field. The ball lands with a velocity of 50 m/s at an angle of 35° below the horizontal. (a) If the player hits the ball 1 m above the playing field, what was the velocity of the ball upon leaving the bat? (b) What was the horizontal distance travelled by the ball? (c) How long was the ball in air? (54.3 m/s; 269 m; 6.56 s)

14. An antiaircraft gun fires shells at 200 m/s at a 60° angle to the horizontal. An enemy plane flies toward the gun at 300 m/s staying at an altitude of 500 m off the ground. How far away (horizontally) must the plane be when the gun fires for the shell to hit the plane? Explain why you get two answers to this problem.
This part of the H.W will NOT be on the first quiz you take. This part of the H.W is intended to remind you of some of the concepts you learned in Freshman Physics as well as some upcoming mathematical pre-requisites. You may look up the background Physics online. The Math problems are about figuring things out.

15. In analyzing certain situations, it turns out that the commonly used horizontal (x) – vertical (y) coordinate system becomes cumbersome or makes the analysis more complicated. A slanted/rotated coordinate system becomes more suitable in such situations. One such coordinate system is shown below and a vector in that coordinate system is drawn. Find the components of the vector (line with arrow) in the new coordinate system (dashed lines). Note that the new x –y axes are also perpendicular to each other just as the horizontal (x) – vertical (y) axes were perpendicular to each other.

16. The same argument as above; Find the components of the vector (line with arrow) in the new coordinate system (dashed lines).

Newton’s 2nd Law: \( \vec{F}_{\text{NET}} = m\vec{a} \)

The \( \vec{F}_{\text{NET}} \) in the equation above refers to the vector sum of forces acting on an object. Sometimes \( \vec{F}_{\text{NET}} \) is zero as evidenced by the fact that the object appears stationary. In such cases, the law helps us find unknown forces (here trigonometry becomes a very helpful tool). Use this concept to figure out the following problem.

17. A group of students are planning on hanging a sign advertising the new school play. They paint the sign on a rectangular MDF plank that has a mass of 10kg and attach an eyehook at the top so that ropes can be tied to it. They plan on hanging the sign as shown. The downward force is 100N. What is the tension in the ropes if they both make the angles shown in the diagram? (Hint: Tension points along the ropes. What is balancing the downward 100N?)

Fun Fact: You could never hang the sign with the ropes horizontal!!
Conservation of Mechanical Energy: The sum of kinetic energy and Potential energy in a system where friction and applied forces can be ignored, remains constant i.e is conserved.

\[
\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f
\]

where \(v_i\) and \(h_i\) are the initial height and \(v_f\) and \(h_f\) are the final velocity and height, \(m\) is the mass of the object.

18. A roller coaster ride at an amusement park starts at A and goes around the loop-the-loop of radius \(R = 4.9\) m. When it is at the top of the loop, point B, it has a speed of \(7\) m/s. Assuming that the ride starts at rest at point A, and no energy is lost to friction or other forces, find \(h\).

Fun Fact: An object in circular motion **can not** have a speed of zero at the top of the circle – in fact there exists a minimum speed that the object **has to** have at the top in order for it to stay in the circular path. Watch: http://www.youtube.com/watch?v=wiZoVAZGgsw

Conservation of Linear Momentum: The vector sum of the linear momenta of an interacting system remains constant in the absence of external forces i.e total momentum is conserved. This principle is used often in analyzing collisions.

\[
m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}.
\]

\(i\) and \(f\) refer to before and after collision values, \(v\) stands for velocity, \(m\) for mass of colliding objects, 1 and 2 refer to the two objects colliding. Sometimes, objects stick together after collision and move together as one i.e \(v_{1f} = v_{2f}\).

19. Ryan from the science team has rigged a NERF gun so that it fires darts really fast. In order to find the new improved speed of the darts shot from the modified NERF gun, he shoots the darts onto a wooden block. The Velcro-tipped NERF dart shot from the gun sticks to a wooden block and the block’s speed is measured. The block has a mass of 0.100 kg, the dart’s mass is 0.020 kg and the block is seen to be moving at 2m/s after the collision.

(a) What was the dart’s speed if the block was initially at rest?

(b) The Kinetic Energy (measured in Joules) of an object can be found using the formula \(\frac{1}{2}mv^2\).

What was the initial Kinetic Energy of the dart? What was the final kinetic energy of the block + dart?

Fun Fact: In collisions, momentum is always conserved but kinetic energy may not be conserved.
EXTRA CREDIT (A, B, C, D, E – attempt them on a separate sheet of paper)

A. A motorcycle moving with uniform acceleration takes 10s and 20s to travel two successive quarter kilometers. How much further will it travel before coming to rest? (Ans. 10.42 m)

B. A body moving in a straight line with uniform acceleration describes three successive equal distances in time intervals $t_1$, $t_2$ and $t_3$ respectively. Show that

$$\frac{1}{t_1} - \frac{1}{t_2} + \frac{1}{t_3} = \frac{3}{t_1 + t_2 + t_3}$$

(yes that is a minus between the first two terms!!)

C. An alert hiker sees a boulder fall from the top of a distant cliff and notes that it takes 1.30 s to fall the last third of the way to the ground. What is the height of the cliff in m?

E. A ball "A" is dropped from a height, "h", when another ball, "B" is thrown upward in the same vertical line from the ground. At the instant the balls collide in the air, the speed of "A" is twice that of "B". Find the height at which the balls collide. ($y = \frac{2h}{3}$)

F. A particle is released from a height of "3h". Find the ratios of time taken to fall through successive equal heights "h". ($t_1 : t_2 : t_3 :: 1 : \sqrt{2} - 1 : \sqrt{3} - \sqrt{2}$)