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AP PHYSICS 1 & 2

# The Ultimate Student's Guide to AP Physics 1 & 2

EVERYTHING YOU NEED TO GET STARTED

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# Introduction

AP Physics 1 & 2 are no walk in the park. Some AP courses have a ton of content. Some have conceptual difficulty. But AP Physics 1 & 2 have both. That's why this is one of our largest, most comprehensive AP subject eBooks yet.

Here you'll find an expansive library of guides designed to refine your conceptual knowledge and ability to solve AP problems. We've also packed in our Ultimate List of AP Physics 1 & 2 Tips, as well as a one-month study guide.

This book features information from the **Albert Blog**, where new academic resources are published every day of the week. Be sure to regularly check the blog and subscribe to hear about our new posts. You can also find tips and study guides for your AP Classes, and admissions advice for your dream school on our blog.

E-mail us at hello@albert.io if you have any questions, suggestions, or comments!

*Last Updated: January 2017*

# About Us

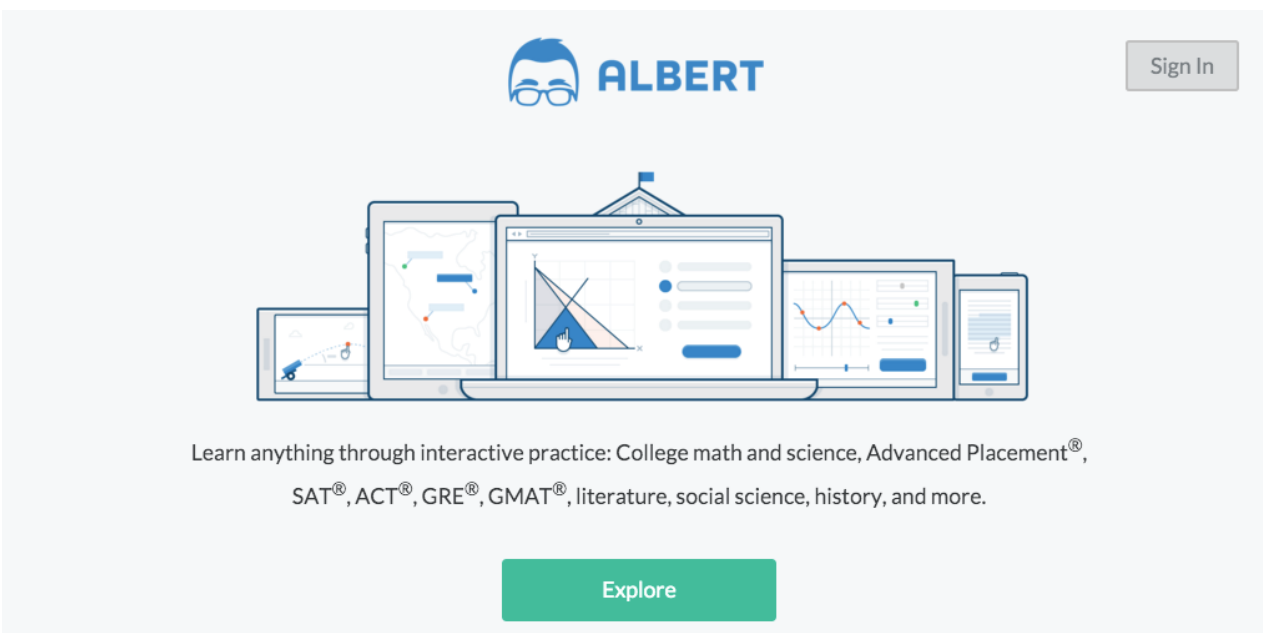
## What is Albert?

Albert bridges the gap between learning and mastery with interactive content written by world-class educators.

## We offer:

- Tens of thousands of AP-style practice questions in all the major APs
- A complete competitive online leaderboard to see where you stand compared to others
- Immediate feedback on each question answered
- An easy to access platform from any Internet-enabled device
- In-depth personal statistics to track your progress
- Intuitive classroom tools for teachers and administrators

Discover why thousands of students and educators trust Albert



# Why Educators Love Us

We asked teachers how their students did after using Albert.

**Here is what they had to say:**

*My students had an 81.2% passing rate - the previous year was 76% (the highest rate in our county)! I am thrilled. I had 64 students total, with 6 receiving 5s, 19 scoring 4s, 27 receiving 3s, 10 scored 2s and 2 received 1s.*

Susan M., JP Taravella High

*70% of my students scored 3 or higher. This is up from last year, and is also well above the national average. Needless to say, I am very happy with my students' success. I used Albert more intentionally this year. In the beginning of the year, I wanted students simply to answer questions and practice. Once they had 150-200 questions answered, we looked for trends, strengths, and weaknesses and worked on addressing them. Students were tasked with increasing their answer accuracy no matter how many questions it took, then they set their own goals (some wanted to focus around tone; others needed practice with meaning as a whole).*

Bill S., Lapeer High School

*Last year 40% passed with 3s and 4s. This year 87% passed, most had 4s and 5s. We used the stimulus-based multiple choice questions throughout the year and as review for the exam. I think it helped tremendously.*

Alice P., First Baptist Christian Academy

# Why Students Love Us

We asked students how they did after using Albert.

**Here is what they had to say:**

*I scored very well this year – four 5s and one 4. Albert helped me get used to the types of questions asked on the exam and overall my scores were better this year.*

Robyn G., Chambersburg Area Senior High School

*Last year was my first year taking an AP test, and unfortunately I did not do as well as I had hoped. The subject had not been my best, and that was definitely displayed on my performance. However this year, I made a much higher score on my AP test. The previous year had been AP World History and I had made a 2. For this year it was AP English Language, and I scored a 4. There was a definite jump in my score, because Albert pushed me to focus on my weaknesses and form them into strengths.*

Charlotte R., Rome High

*I scored a 4 on AP Biology, much higher than expected. Albert was an effective resource to guide me through AP Biology. Keeping up with it consistently all year as I learned the lesson in class was crucial to reinforcing my understanding and long-term memorization of Biology. After class each day, Albert helped to sink in the ideas that I was taught in the morning.*

Lily O., Wake Forest High School

# How to Approach AP Physics 1 & 2 Multiple Choice

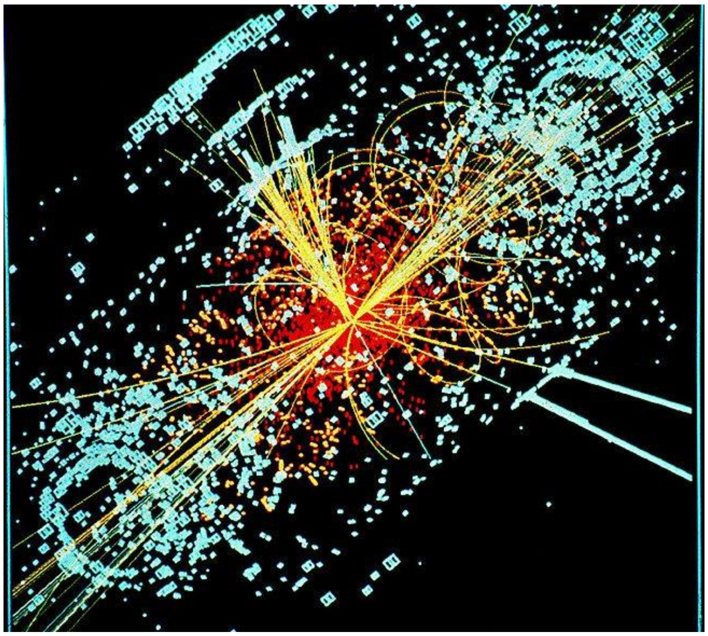


*Image Source: Wikimedia Commons*

As part of our study guide for the AP Physics 1 and AP Physics 2, we now reveal winning strategies for success on the multiple-choice section.

Most students are a little overwhelmed to say the least, when faced with 50 physics multiple-choice questions. However, if you take our advice, study carefully and work consistently, you'll dramatically increase your chances of scoring a 5!

We'll give you some tips for studying for the AP Physics 1 and 2 multiple-choice as well as some killer advice which will make you a winner on the exam!

And now for the good stuff read the following sections.

# How to Approach AP Physics 1 & 2 Multiple Choice Cont.

## Understanding the Format of the Exams

You can read the official description **here**. The main thing I want to point out is that there are two kinds of multiple-choice questions:

1. 45 “single-select” questions with only one correct answer

2. New for AP Physics 1 and 2! Five “multi-correct” questions with *two correct answers*. You have to select *both* correct answers to get credit for the question.

## How to Prepare for the Multiple-Choice Section

**1. Review the material.** This is important, but make sure that you don’t spend too long on it, because you might not leave enough time for the next step!

**2. Practice, Practice, Practice!** This is the most important You can find practice questions in a few places:

- Official sample questions from the College Board **here** and **here**

- The Albert.io website also has **hundreds of practice questions**

- Review books like Barron’s also have many practice questions and practice exams

We recommend that for each topic you review, you should do a few practice multiple-choice (and free-response) questions. In the final stage of your exam prep, take a few timed full-length practice exams.

# How to Approach AP Physics 1 & 2 Multiple Choice Cont.

### How to Answer AP Physics 1 and 2 Multiple-Choice Questions

**1. Read, and reread the question.** Make sure you understand what you're being asked. The exams ask questions in many different ways. Students have lost many points by rushing to answer a question without reading it carefully.

**2. Pace yourself.** If a question takes too long, move on! It's not worth it to spend too much time on hard questions if it means you run out of time for the easy ones!

**3. If you don't know the answer, make a guess and mark the question.** You can come back to it if you have time.

**4. Set a target of 10 questions every 15 minutes.** Then you'll be left with 15 minutes spare, if you need more time or if you want to review questions.

**5. Answer every question.** There's no negative grading, so there's no reason for leaving an answer out. If you just can't figure it out, guess! At least you'll have a chance of getting it right!

**6. Use the formula sheet.** These will be provided at the exam, but you can download one for **AP Physics 1** and **AP Physics 2**.

**7. Use a calculator.** Most scientific and graphing calculators (except those with a qwerty keyboard) are allowed for the entire exam.

# How to Approach AP Physics 1 & 2 Multiple Choice Cont.

## Sample AP Physics 1 & 2 Multiple-Choice Questions

For your study guide to AP Physics 1 and 2 multiple-choice, we'll now go through a few practice questions from the official AP sample questions.

### AP Physics 1

First, one from AP Physics 1: question 13 (on page 166) at **this link**. Here you need to rank magnitudes of acceleration by examining the graph. You should note two things, which show you how important it is to read the question carefully. Firstly, this is a *velocity-time* graph. If you mistook it for a *position-time* graph, you probably wouldn't get the right answer. Secondly, it's asking you to compare the sizes of the *average acceleration, not the instantaneous acceleration*. The instantaneous acceleration is the slope of the graph. It has its largest value at the beginning of AB, but the average velocity is not biggest during this segment. To find the average velocity, find the slope of a straight line drawn from A to B.

So to answer the question, we need to rank the slopes of the above straight line from A to B and the slopes of the lines in the other three segments. Right off the bat, we can see that BC has a slope of zero, which means that $a_{BC}$ is the smallest acceleration. The only choice for which this is true is (D), so this is sufficient to tell us that (D) is the right answer.  We didn't have to do any calculation at all! If you want to, you can check, by inspection that (D) has the other accelerations in the right order.

### AP Physics 2

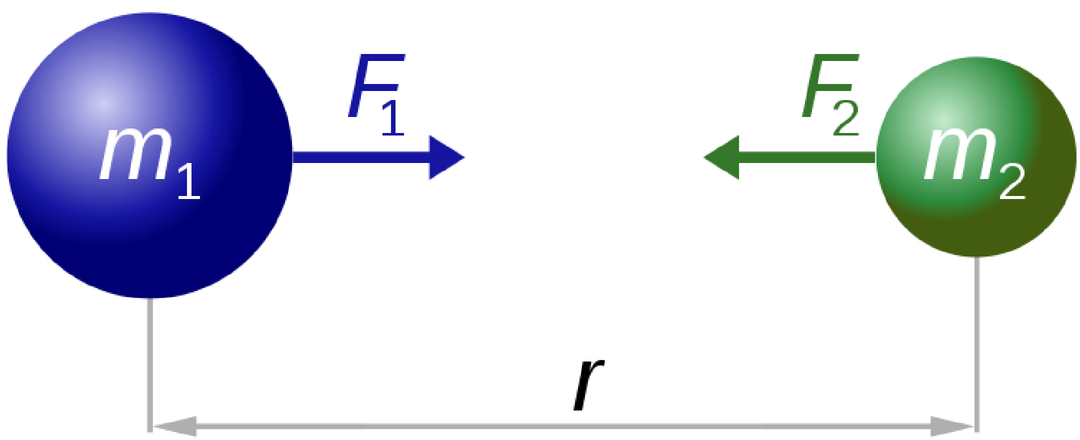
Now, let's take a gander at a sample question from AP Physics 2. Note that this question is one of the *new multi-correct questions*, where you must mark two correct answer choices in order to get credit for the question. We'll look at question 23 on page 207 at **this link**. Again, you have to read the question carefully and understand what it's asking. It deals with the ideal gas law and how to relate it to a graph of the pressure vs. temperature.

# How to Approach AP Physics 1 & 2 Multiple Choice Cont.

When you read the question, did you notice that the temperature is in *Celsius*, not *kelvin*? If you didn't notice this and take it into account, you would get the wrong answer! The ideal gas law, $PV = nRT$, is only true for temperatures in kelvin, not Celsius. For an ideal gas at zero kelvin (absolute zero), the pressure is zero. Therefore, the graph of $P$ vs. $T$ would go through the origin, which would lead you to believe (falsely) that (B) is correct. Since the temperature is in Celsius, the graph would go through the origin at a negative temperature (-273 °C, corresponding to 0 K), so that (C) is a correct choice. The other correct choice is (A); since an increase in temperature corresponds to an increase in pressure, the slope must be positive. So, you would have to mark both (A) and (C) to get credit for this question.

That's all for now, folks! Did you find our study guide for the AP Physics 1 and 2 multiple-choice useful? What are your favorite exam strategies? Let us know!

# 5 Techniques to Beat the AP Physics Free Response




$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

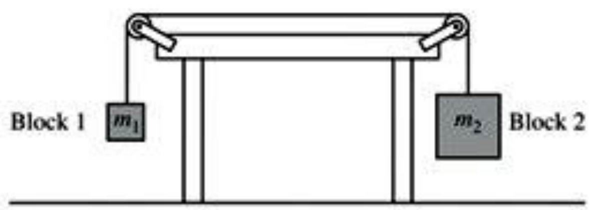
*Image Source: Wikimedia Commons*

The AP Physics Free Response section is composed of 5 questions; you are given 90 minutes to answer them. Knowing the physics is crucial, but beyond that, here are five techniques to minimize errors and maximize points on the AP Physics Free Response section. We apply all of these techniques to 2015 Free Response Question 1.

### Draw the Correct Picture

The AP Physics Free Response section is set up such that you are often required to draw a picture which will be used later in an algebraic equation or expression. The algebra is often used later in a paragraph explaining the physical meaning behind a certain result. Therefore, drawing the *correct picture* is of utmost importance in order to get correct results in later parts of the question.

Here are the prompt and grading scheme for part (a) of 2015 Free Response Question 1:



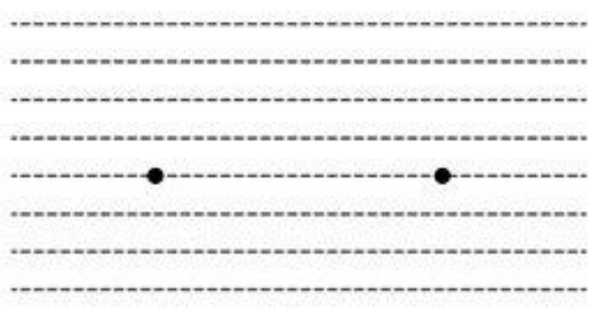

Note: Figure not drawn to scale.

1. (7 points, suggested time 13 minutes)

Two blocks are connected by a string of negligible mass that passes over massless pulleys that turn with negligible friction, as shown in the figure above. The mass $m_2$ of block 2 is greater than the mass $m_1$ of block 1. The blocks are released from rest.

(a) The dots below represent the two blocks. Draw free-body diagrams showing and labeling the forces (not components) exerted on each block. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces.

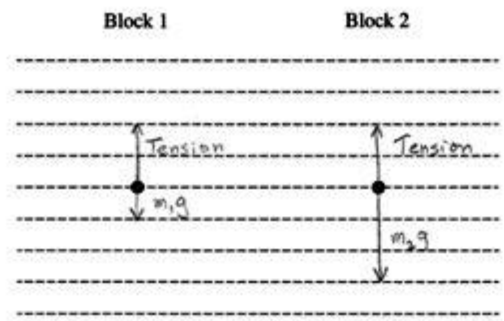
Block 1 Block 2



[Image Source: CollegeBoard]

# 5 Techniques to
# Beat the AP Physics Free Response Cont.

(a) 2 points




| | |
|---|---|
| For drawing two vectors starting on the dots that point upward, have the same length and are labeled as the tension force | 1 point |
| For drawing two vectors starting on the dots that point downward, where the vector for block 1 is smaller than the vector for block 2 and both are labeled as the gravitational force | 1 point |

One earned point is deducted for drawing any extraneous vectors.
One earned point is deducted for vector lengths that do not allow the system to accelerate in the proper direction.

*Image Source: CollegeBoard*

You can imagine that most everyone drew two arrows on each dot with the correct directions. The point of this question is to see if you know (and can show) that the tensile forces on both blocks are the same: the two vectors representing tension must have the same length. Notice that you are provided with dashed lines to "measure" the length of your arrows – use them!

# 5 Techniques to
# Beat the AP Physics Free Response Cont.

**List Relevant Equations**

Here are the prompt and grading scheme for part (b) of 2015 Free Response Question 1:

(b) Derive the magnitude of the acceleration of block 2. Express your answer in terms of $m_1$, $m_2$, and $g$.

(b) 3 points

| | |
|---|---|
| For writing an equation for Newton's second law for block 1 | 1 point |
| $m_1 a = T - m_1 g$ | |
| For writing an equation for Newton's second law for block 2 | 1 point |
| $m_2 a = m_2 g - T$ | |
| For eliminating $T$ to obtain an equation that can be solved for the acceleration | 1 point |
| $T = m_1 a + m_1 g$ | |
| $m_2 a = m_2 g - m_1 a - m_1 g$ | |
| $(m_2 + m_1) a = (m_2 - m_1) g$ | |
| $a = (m_2 - m_1) g/(m_2 + m_1)$ | |

*Image Source: CollegeBoard*

Notice that performing the algebra and arriving at the correct acceleration expression is worth *the same as listing the force equations*, even though doing the algebra is harder. The AP Physics Exams test your knowledge of physics – setting up physical equations is physics, and doing math isn't.

Another way to approach this problem is to treat both masses as part of the same system and consider only external forces on the system:

$$(m_1 + m_2)\, a = m_2 g - m_1 g.$$

This also yields the correct acceleration expression, is faster, and would score full points. It is *not acceptable* just to write down the acceleration

$$a = \frac{(m_2 - m_1)g}{(m_1 + m_2)}.$$

The prompt says to "derive" the acceleration expression, which is a good clue that you should show work.

On the other hand, do not write down irrelevant equations – if the prompt asks for two equations, for example, graders will score only the first two equations you write down.

## Check Limiting Cases

Limiting cases are typically not taught as part of the AP Physics curriculum, but they are easy and quick ways to check if your expression is reasonable. The idea is to push a single variable to an extreme and see if the answer that follows would make sense in the real world. This is easier to see in practice:

Take the acceleration expression for the two-block system obtained above,

$$a = \frac{(m_2 - m_1)g}{(m_1 + m_2)}.$$

We test two limiting cases.

1. $m_1$ is small. If $m_1$ approaches zero, then the expression for a reduces to

$$a = \frac{(m_2 - 0)g}{(0 + m_2)} = g.$$

This makes sense: if $m_1$ has no mass, then we expect $m_2$ to accelerate down in free-fall with acceleration g.

2. $m_1 = m_2$. If the masses are equal, the expression reduces to

$$a = \frac{(m_2 - m_2)g}{(m_2 + m_2)} = 0.$$

This makes sense: the masses are stationary because neither is more massive. The system is in equilibrium with equal masses hanging on either side of the table.

Now, let's see what happens when the expression tested is incorrect. Suppose you made an algebra mistake and came up with an expression like one of the two below:

$$a = \frac{(3m_2 - m_1)g}{(m_1 + 2m_2)}.$$

$$a = \frac{(m_2 + m_1)g}{(m_1 + m_2)}.$$

# 5 Techniques to Beat the AP Physics Free Response Cont.

1. $m_1$ is small. If $m_1$ approaches zero, then the first incorrect expression for a reduces to

$$a = \frac{(3m_2 - 0)g}{(0 + 2m_2)} = \frac{3g}{2}.$$

This makes no sense: if $m_1$ has no mass, then the expression says that $m_2$ accelerates faster than under the influence of gravity. Something is wrong, and we must check our work.

2. $m_1 = m_2$. If the masses are equal, the second incorrect expression reduces to

$$a = \frac{(m_2 + m_2)g}{(m_2 + m_2)} = g.$$

This makes no sense: the masses should be stationary because neither is more massive than the other. Since the (incorrect) expression says the system accelerates with acceleration g, something is wrong and we must check our work.

A disclaimer: checking limiting cases can only tell you if your answer is *incorrect*. It cannot say whether an expression is right – it's perfectly possible for a wrong expression to be right in a limiting case. For example,

$$a = \frac{(m_2 + m_1)g}{(m_1 + m_2)} \text{ is correct when } m_1 = 0.$$

Limiting cases are simply quick smell tests that discard expressions that don't pass the test. They won't *earn* you points on the AP Physics Free Response, but they might alert you to a mistake.

# 5 Techniques to Beat the AP Physics Free Response Cont.

## Use Correct Vocabulary

Physics is not like other subjects in which you are *asked* to use specific vocabulary words – in physics, you usually have no choice but to use physics vocabulary when describing physical phenomena. However, you must use *correct* vocabulary – if you use an incorrect word, you risk losing points on an explanation portion of an AP Physics Free Response question. You should review the differences among the following terms:

- Displacement vs. distance traveled
- Gravitational *acceleration* vs. gravitational *force* (do not just say “gravity”)
- Speed vs. velocity
- Moment of inertia vs. inertia
- Potential energy vs. potential difference vs. electric potential
- Electric field vs. electric force
- Impulse vs. momentum

(AP Physics 2 Only)

- Reflection vs. refraction
- Interference vs. diffraction
- Real image vs. virtual image

## Redo the Algebra

Simply looking over your work doesn’t cut it – if you have time, start from the basic equations and redo any algebra you had to perform to arrive at the answer. In the best case, arrive at the same answer using a different method: say that for our example FRQ, you correctly set up the two $F = ma$ equations,

$$m_1 a = T - m_1 g,$$

$$m_2 a = m_2 g - T.$$

# 5 Techniques to
# Beat the AP Physics Free Response Cont.

If you first solved this system by solving for T in the first equation and substituting in the second,

$$T = m_1g + m_1a$$

$$m_2a = m_2g - (m_1g + m_1a)$$

you could solve it again by solving for T in the second equation and substituting in the first,

$$T = m_2g - m_2a$$

$$m_1a = (m_2g - m_2a) - m_1g$$

and you could even solve it again by adding the equations together,

$$m_1a + m_2a = m_2g - m_1g.$$

All three methods yield the same result, as they should.

# 5 Techniques to Beat the AP Physics Free Response Cont.

## Wrapping Up Five Techniques to Beat the AP Physics Free Response

**Draw the Correct Picture**

- For vectors, both length and direction matter. Make sure to label all parts of the drawing.

**List Relevant Equations**

- Start from the basic equations of physics. Do not skip steps!

**Check Limiting Cases**

- Push one variable to an extreme to check that your expression yields a reasonable answer.

**Use Correct Vocabulary**

- Words in physics have specific meanings – use the correct word.

**Redo the Algebra**

- Don't just look over your math – do it again, using a different method if possible.

# Forces Review

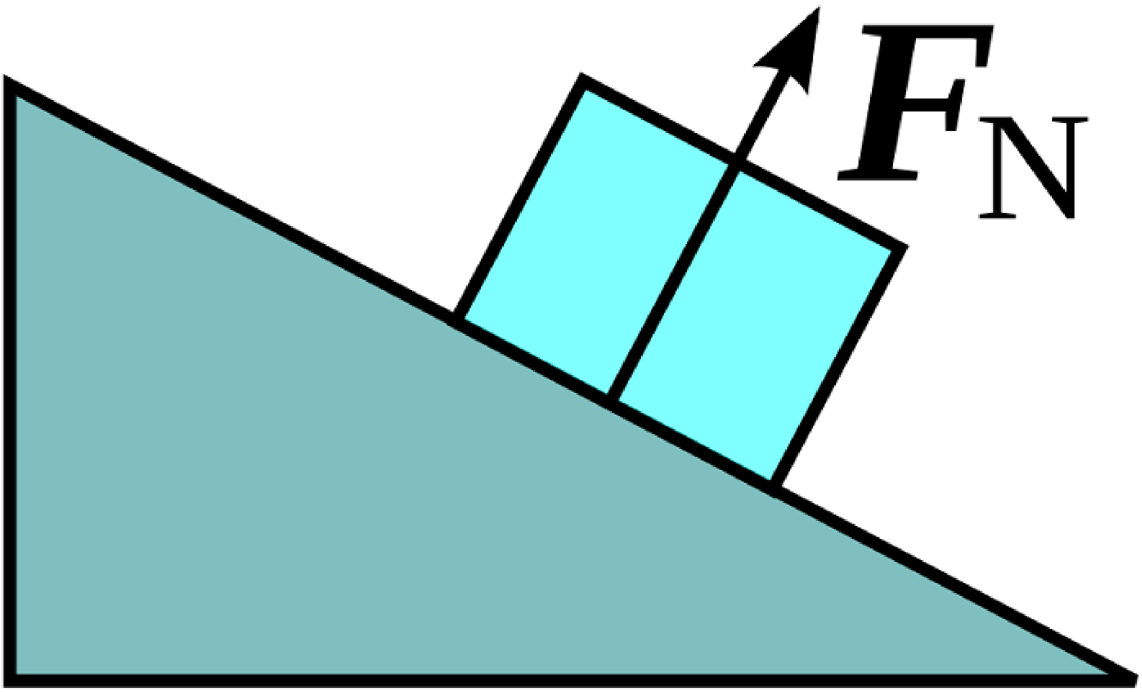



Image Source: Wikimedia Commons

A force is an interaction between two objects that causes both objects to change their motion. In this AP Physics 1 & 2 Review, we cover Newton's Laws of Motion, the relation between force and potential energy, and the different types of forces tested on the AP Physics 1 and 2 Exams.

# Forces Review Cont.

## Newton's Laws

Newton's First Law concerns itself with the *absence* of a net force:

> *Objects not acted on by a net force will not accelerate in an inertial frame of reference.*

AP Physics only concerns itself with inertial reference frames, so this law isn't that important for the test. All it says is that if the net force $F_{net}$ is zero, then the acceleration a is also zero.

Newton's Second Law relates forces (quantities that we can feel) to accelerations and ultimately to positions (quantities that we can see):

$$\vec{F_{net}} = m\vec{a}.$$

$F_{net}$ is the net force acting on the object, *m* is the mass of the object, and a is its acceleration.

Newton's Third Law states that forces exist in "pairs:"

*Every force has a corresponding reaction force of opposite direction and identical magnitude.*

Suppose you have two objects, 1 and 2. The sum of the force from 1 on 2 $\vec{F_{21}}$ and the force from 2 on 1 $\vec{F_{12}}$ is zero:

$$\vec{F_{21}} + \vec{F_{12}} = 0$$

$$\vec{F_{21}} = -\vec{F_{12}}.$$

# Forces Review Cont.

We say that $\vec{F_{21}}$ and $\vec{F_{12}}$ are an "action-reaction force pair." We cover examples of force pairs when we study the different types of forces.

An elementary misunderstanding of force pairs is this question: "If the forces $\vec{F_{21}}$ and $\vec{F_{12}}$ sum to zero, how can anything accelerate?" Though the two forces sum to zero, they act on different objects: $\vec{F_{21}}$ acts on object 2, and $\vec{F_{12}}$ acts on object 1. The force on *either* object 1 or object 2 is nonzero, and both objects accelerate.

## Force and Potential Energy

Potential energy is sometimes called the "ability to do work." In addition to that definition, potential energy, $U$, is also related to any conservative force $F$.

Suppose a force $F$ is the only force acting on an object, which travels through a small distance $\Delta x$ parallel to $F$. The potential energy $U$ satisfies

$$\Delta U = -F\Delta x,$$

or

$$F = -\frac{\Delta U}{\Delta x}.$$

In words,

The change in potential energy is minus the product of force and displacement.

The force is minus the slope of the graph of potential energy versus position.

This is true for any *conservative* force. For now, you should know that conservative forces depend only on position and do not dissipate energy. The only non-conservative forces in AP Physics 1 & 2 are the frictional and magnetic forces.

# Forces Review Cont.

## The Gravitational Force

According to Newton's Universal Law of Gravitation, the force between two objects of masses *M* and *m* separated by a distance *r* is

$$F = \frac{GMm}{r^2},$$

*G* is called the Gravitational Constant;

$$G = 6.67 \times 10^{-11} Nm^2kg^{-2}.$$

This force acts on both objects: mass *M* experiences a force *F* towards *m*, and mass *m* experiences a force of equal magnitude towards *M*. The forces on *M* and *m* are an action – reaction pair and always sum to zero. Objects on the earth always have roughly the same separation *r* from the earth's center because the earth is so large. In this case, we can combine *G*, *M*, and *r* into a single constant, *g*. The gravitational force

$$F = \frac{GMm}{r^2}$$

Becomes

$$F = m\frac{GM}{r^2}$$

Or just

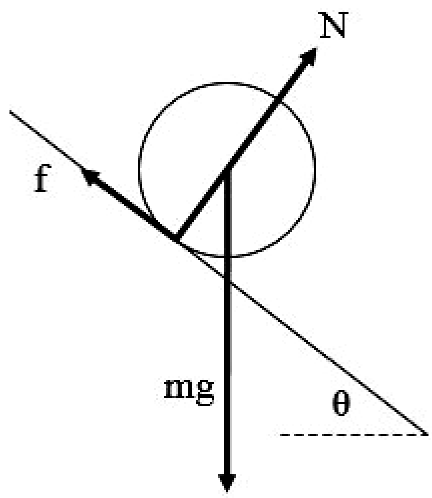
$$F = mg.$$

The gravitational acceleration near the earth's surface is $g=9.8ms^{-2}$.

# Forces Review Cont.

## The Normal Force

The normal force occurs because solid real-world objects cannot occupy the same space. Take the example of a ball rolling down an incline of angle $\vartheta$:




There is a force from gravity pulling the ball directly down, but we know from experience that gravity does not pull an object through a solid surface. This is because any surface will exert a force, the normal force, on an object that is pushing into it. The normal force is always pointed away from and perpendicular to the plane of the surface. The magnitude of the normal force is just enough to cancel any forces that would move the object into the surface. In our example of the ball on the incline, the perpendicular acceleration and perpendicular net force on the ball is zero, because the normal force acting on the ball counteracts the force of gravity in the direction perpendicular to the surface.

$$\vec{F_{net,\perp}} = 0.$$

# Forces Review Cont.

In this case, the forces perpendicular to the incline are the normal force and the perpendicular component of gravity, *mg cosϑ*:

$$F_{net,\perp} = 0 = N - mg\cos\theta.$$

Thus, *N* = *mg cosϑ*. The incline pushes up on the ball with force of magnitude *N*, and the ball pushes down on the incline with a force of equal magnitude. (Please note that these forces are not action-reaction pairs in terms of Newton's Third Law of Motion. They simply sum to zero because the ball is not accelerating in the perpendicular direction. The gravitational force of the ball on the Earth is the actual reaction force of the gravitational force of the Earth on the ball).

## The Frictional Force

The harder you push a block against any flat surface, the harder it is for the block to slide. This difficulty is caused by the frictional force, which opposes motion when to objects rub against one another. When the frictional force is large enough to completely prevent motion, it is called static friction. When the frictional force opposes motion but does not completely stop motion, it is referred to as kinetic friction. This physical reality is expressed through the *coefficient of friction*, $\mu$ (pronounced mu). For two objects rubbing against each other, $\mu$ varies depending on if the objects are in relative motion (kinetic friction, described with $\mu_k$) or stationary (static friction, described with $\mu_s$). If *f* and *N* are the frictional and normal forces between the two objects, then

$$f_s \leq \mu_s N \text{ (Static)}$$

$$f_k = \mu_k N \text{ (Kinetic).}$$

# Forces Review Cont.

The static frictional force can be any magnitude up to a maximum value of $\mu_s N$. This means that so long as the force on an object is less than $\mu_s N$, the static frictional forces can prevent objects from moving when rubbing against one another. If the force on the object is greater than $\mu_s N$, the motion will not be prevented. There is still friction, called kinetic friction, but its magnitude is always equal to $\mu_k N$ and always acts *opposite to the velocity*. Typically, $\mu_s > \mu_k$.

Let's look at an example to understand static and kinetic friction more clearly.

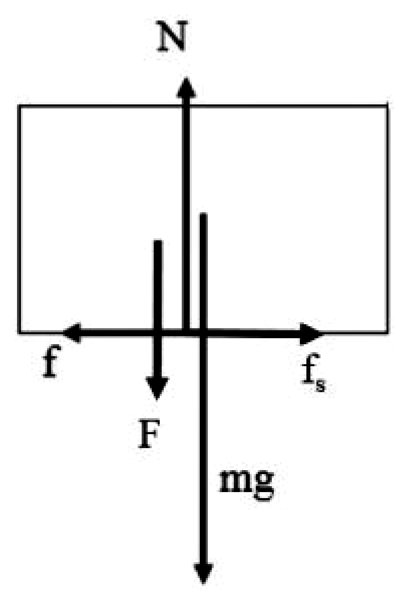
**Block on the Floor**

*A block of mass m = 1.00kg sits on the floor; the coefficient of static friction is $\mu_s$ = 1.5. You push down on the box with force F = 2.00N and your friend pushes to the left with a variable force f. Calculate the static friction force $f_s$*

*(a) when f = 1.0 Nf=1.0N*

*(b) just before the block begins to slide?*

**Solution:**



# Forces Review Cont.

For problems involving friction, we generally need to find the normal force and maximum static friction force. The net force perpendicular to the floor must be zero:

$$0 = N - mg - F$$

$$N = mg + F = (1.00kg)(9.8ms^{-2}) + 2.00N = 11.8N.$$

Therefore, $\mu_s N$ = (1.5) (11.8$N$) = 17.7$N$

(a) Remember that the static friction force always makes the net force zero. In the horizontal direction, we must have

$$0 = f - f_s$$

$$f_s = f = 1.0N.$$

We always have to check that static friction is less than the maximum value, $\mu_s N$. In this case, $f_s$ is clearly less than $\mu_s N$ = 17.7$N$.

(b) The block starts to slide when the force pushing the block exceeds the maximum static friction, $\mu_{s.}$ Therefore, the static friction will equal $\mu_s N$ just before the block starts to slide: in this case, $f_s$ = $\mu_s N$ = 17.7$N$ just before the block starts sliding.

# Forces Review Cont.

## The Spring Force

The further you stretch or compress a spring, the more force it exerts on your hand. All springs in AP Physics 1 & 2 obey *Hooke's Law,*

$$F = -kx.$$

*F* is the force exerted by the spring on your hand, and *x* is the displacement of the end of the spring from equilibrium, where there is no force. The negative sign means that *x* and *F* have opposite signs: if you stretch the spring to the right, the spring force on your hand points to the left. The coefficient k is called the *spring constant* and varies from spring to spring. It has units of *N*/*m*.

Related to Hooke's Law is the *stored potential energy in a spring*,

$$U_{spr} = \frac{1}{2}kx^2$$

Evidently, the slope of the graph of $U_{spr}$ versus $x$ is $-kx$. The slope of the graph is $kx$. $F = -dU/dx$.

## The Electrostatic Force

According to Coulomb's Law, the force between two objects of charges *Q* and *q* separated by a distance *r* is

$$F = \frac{kQq}{r^2},$$

# Forces Review Cont.

k is called Coulomb's constant; $k = 8.99 \times 10^9\ Nm^2\ C^{-2}$. Sometimes k is written as

$$k = \frac{1}{4\pi\epsilon_0},$$

but it retains the same value $8.99 \times 10^9\ Nm^2\ C^{-2}$.

This force acts on both objects: charge $Q$ experiences a force $F$ towards $q$, and charge $q$ experiences a force of equal magnitude towards $Q$. The forces on $Q$ and $q$ are an action –reaction pair and always sum to zero. (Notice the similarities between the gravitational and electrostatic forces!)

The force on a charge $q$ in a uniform electric field $E$ is or just $F = qE$. This is similar to the force on a mass in earth's uniform gravitational field, $F = mg$.

### The Magnetic Force on a Moving Charge

Suppose a charge $q$ moves with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. The force on the charge is

$$F = q\vec{v} \times \vec{B}.$$

The $\times$ signifies the vector cross product, performed with the right-hand rule. (If your right index finger points along $v$ and your middle finger points along $B$, then your thumb points along $v \times B$.)

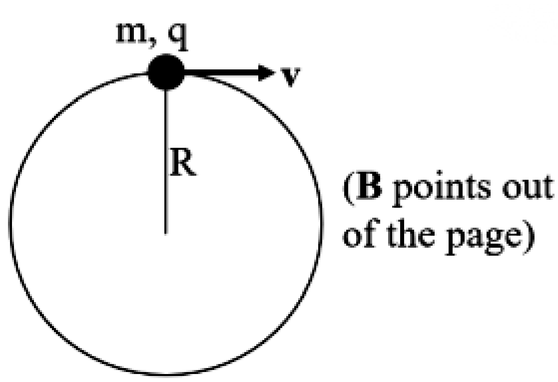
Note that the magnetic force is always perpendicular to the velocity. The centripetal force is also always perpendicular to the velocity, which is our next example.

# Forces Review Cont.

**A Circularly Moving Charge**

A point object of mass *m* and positive charge *q* moves in uniform circular motion of radius *R* perpendicularly to a uniform magnetic field of strength *B*. Find the speed of the object, *v*.

***Solution:***




The only force on the charge is the magnetic force, which supplies the centripetal force required to keep the charge moving in a circle. Since *v* and *B* are perpendicular, their cross product has magnitude *vB*. You can check from the figure that $v \times B$ points to the center of the circle, as it must for circular motion. Therefore,

$$F_{net} = qvB = \frac{mv^2}{R}$$

Solving this equation, we obtain $v = qBR/m$. In this problem we relied on the fact that $a = v^2/R$ for objects undergoing uniform circular motion.

# Forces Review Cont.

## The Magnetic Force on a Current-Carrying Wire

A current is composed of moving charges; the definition of current is:

$$I = \frac{\Delta q}{\Delta t}.$$

In this equation, $I$ is the current, $\Delta q$ is the charge flowing past some point, and $\Delta t$ is the time taken to do so. Using this in the magnetic force equation for moving charges,

$$F = q\vec{v} \times \vec{B}$$

$$= q\frac{\vec{\Delta l}}{\Delta t} \times \vec{B}$$

$$= \frac{q}{\Delta t}\vec{\Delta l} \times \vec{B}$$

$$F = I\vec{l} \times \vec{B}.$$

The equation $F = I\vec{l} \times \vec{B}$ makes physical sense: a higher current, a longer wire, and a higher magnetic field all produce a greater magnetic force.

# Forces Review Cont.

## Wrapping Up Forces for the AP Physics 1 & 2 Exams

### Newton's First Law

Objects not acted on by a net force will not accelerate in an inertial frame of reference.

### Newton's Second Law

$$\vec{F_{net}} = m\vec{a}.$$

### Newton's Third Law

Every force has a corresponding reaction force of opposite direction and identical magnitude.

### Force and Potential Energy

$$\Delta U = -F\Delta x.$$

$$F = -\frac{\Delta U}{\Delta x}.$$

In words,

The change in potential energy is minus the product of force and displacement.

The force is minus the slope of the graph of potential energy versus position.

# Forces Review Cont.

**The Gravitational Force**

$F = \frac{GMm}{r^2}$ (general).

$F = mg$ (near earth's surface).

**The Normal Force**

$\vec{F_{net,\perp}} = 0.$

**The Frictional Force**

$f_s \leq \mu_s N$ (Static).

$f_k \leq \mu_k N$ (Kinetic).

**The Spring Force**

$F = -kx.$

**The Electrostatic Force**

$F = \frac{kQq}{r^2}$ (Coulomb's Law).

$F = qE$ (Uniform Electric Field).

# Forces Review Cont.

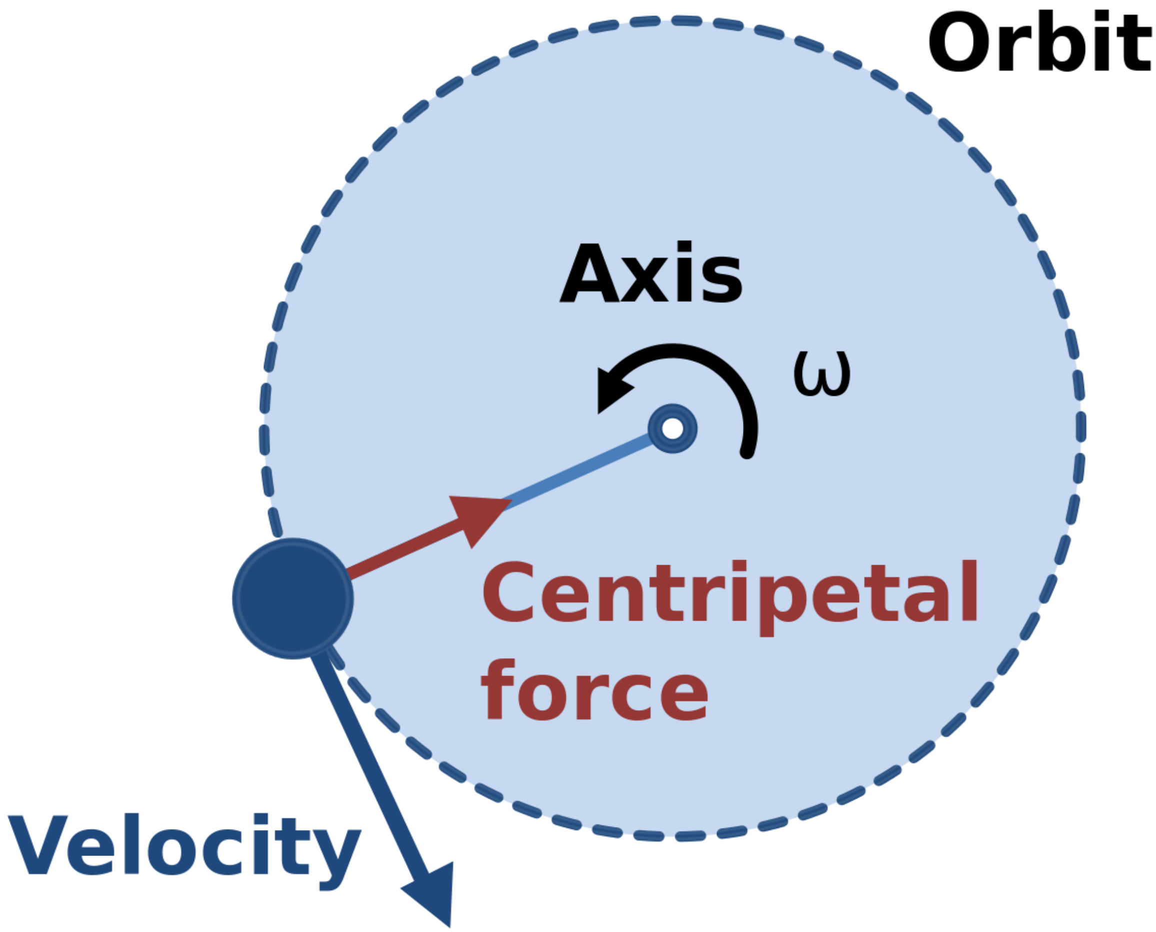
**The Magnetic Force on a Moving Charge**

$$F = q\vec{v} \times \vec{B}.$$

**The Magnetic Force on a Current-Carrying Wire**

$$F = I\vec{l} \times \vec{B}.$$

# Centripetal Forces




[Image Source: Wikimedia Commons]

You might have heard that centripetal forces are "not true forces," that they continuously change direction, and that particles under a centripetal force accelerate but still move at a constant speed. All of these properties are counter intuitive at first glance, but this article will straighten out the challenging aspects of circular motion and give you some AP Physics 1 practice.

# Centripetal Forces Cont.

## The Centripetal Force is a Type of Net Force

Remember adding force vectors on a free-body diagram and drawing a new vector which represents the sum of all forces? That new vector is the net force, and the net force is the "*F*" in Newton's second law, $F = ma$.

Suppose a particle moves in a circle at constant speed. We call the net force on the particle the *centripetal* force. The centripetal force is not a "true force" in the sense that, in general, it doesn't come from a specific interaction in the same way that, say, the gravitational and normal forces do. It is the *sum* of all "true forces" of all interactions, and only for the special case of curved paths. This is what authors and teachers mean when they say some external forces "provide" or "supply" the centripetal force: when you add all external forces, the result is the centripetal force.

## The Centripetal Force Points to the Center of Rotation

If you swing a ball on a string in a horizontal circular path, you pull on the string, which pulls on the ball. In this case, the only force on the ball is the string tension (ignoring gravity), and we have $\vec{F}_{net} = \vec{F}_c = \vec{T}$, where $\vec{T}$ is the tension from the string on the ball.

Since the string tension points towards the center of rotation (your hand), so does the centripetal force. By Newton's Second Law $\vec{F}_{net} = m\vec{a}$, the acceleration points towards the center of rotation as well. This generalizes to any particle moving in a circle:

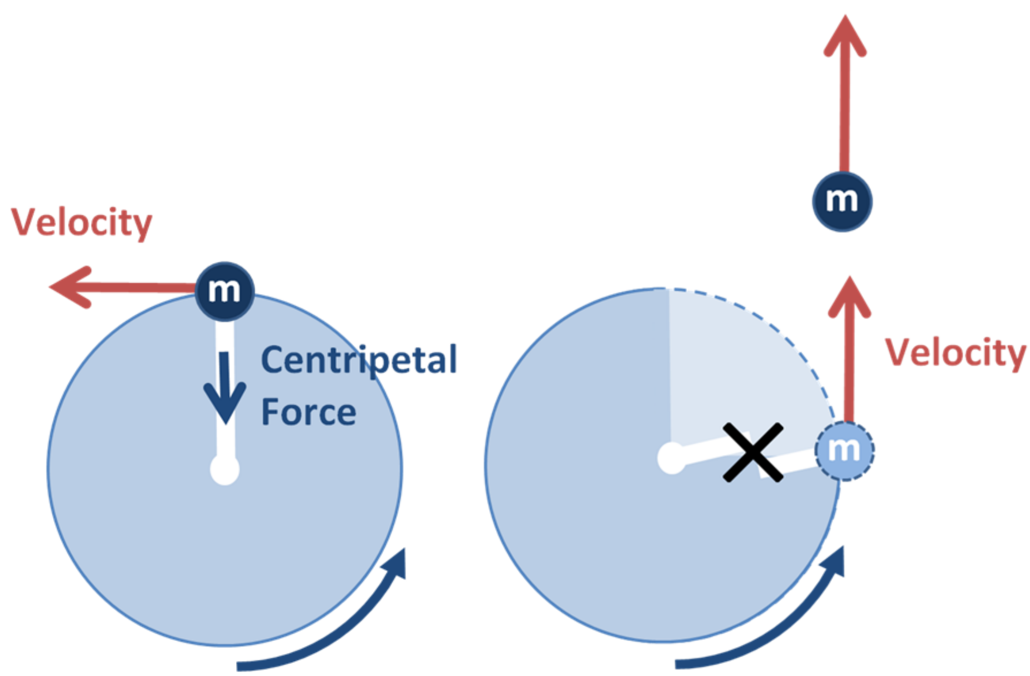
> *The centripetal force and acceleration of a particle moving circularly at constant speed both point to the center of rotation.*

As the ball moves around the circle, the string changes direction, but always connects the center of the circle to the ball. This is why centripetal forces (and accelerations) change direction.

# Centripetal Forces Cont.

On the other hand, how can the particle have an acceleration if its speed is constant? Recall the definition of acceleration: change in velocity per time. Acceleration and velocity are vectors; speed is not. Though the particle's speed is constant, its velocity is continuously changing direction, so the acceleration is nonzero. The variation of velocity with time is similar to the motion of a minute hand on a clock: though its length is constant (particle speed is constant), it points in different directions at different times.

If you release the ball, it will fly in a straight line tangentially out of the circle, since it moves in the direction of its *velocity:*




[*Image Source: Wikimedia Commons*]

From the figure, we see that *centripetal forces are perpendicular to particle velocities.*(This holds only for circular motion and not for elliptical or more complicated motions, which are not tested on the AP Physics 1 exam.)

# Centripetal Forces Cont.

## The Centripetal Force with Algebra

It would be fun to draw pictures of balls and strings all day, but the AP Physics 1 exam is algebra-based, so you'll have to write equations, too. The derivation of the centripetal force formula involves is higher-level than AP Physics 1, so I'll just state it the formula itself. Suppose a particle of mass *m* moves at speed *v* in a circle of radius *r*

$$F_c = \frac{mv^2}{r},$$

and by Newton's Second Law,

$$a_c = \frac{v^2}{r}.$$

Again, both $F_c$ and $a_c$ point to the center of the circle.

Let's make sense of these equations.

1. As *m* increases, so does *F*: a heavier mass requires more force to revolve.
2. As *v* increases, so does *F*: more force is required to make a given mass swing more quickly.
3. As *r* increases, *F* decreases: if the particle's speed is fixed, then the longer the string, the weaker you pull on it.

For circular motion, the angular speed $\omega$ (change in radian angle per time) is related to *v* and *r* by $\omega = v/r$. Therefore,

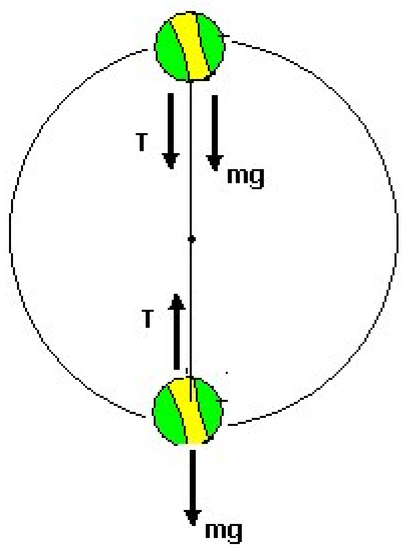
$$F_c = m\omega^2 r, \text{ and } a_c = \omega^2 r.$$

# Centripetal Forces Cont.

## Centripetal Forces on the AP Physics 1 Test

These centripetal force problems would likely appear on an AP Physics 1 exam. There are a couple "classic" problems about centripetal forces which spawn variants on almost every test, so learn and review each type! When solving these, remember that the centripetal force is the *sum of all forces* and not a true force itself.

**Swinging a Ball:**




[*Image Source: MelbourneThomas*]

*You swing a m = 1.0kg ball with a string in a vertical circle of radius r = 1.0m at constant speed v = 4.0m/s. Taking g = 9.8N/kg, find the tension in the string when the ball is at*

*(a) the top of its orbit*

*(b) the bottom of its orbit*

# Centripetal Forces Cont.

**Solution:**

The magnitude of the centripetal force is a constant $F_{net} = \frac{mv^2}{r} = 16N$. Draw free-body diagrams on the balls as in the figure. Here's the crux: while tension always points towards the center of the circle, gravity does not. (We avoided this in our earlier example by using a *horizontal* circle, in which the force of gravity has no component in the plane of rotation).

(a) At the top of the circle, both forces point in the direction of the centripetal force, so we don't need vector symbols:

$$F_{net} = T_{top} + mg$$

$$T_{top} = F_{net} - mg = 16N - (1kg)(9.8N/kg) = 6.2N,$$

in the downward direction.

(b) At the bottom, $\vec{T}$ points up and *mg* points down. The centripetal force points up (towards the center of the circle), so

$$F_{net} = T_{bottom} - mg$$

$$T_{bottom} = F_{net} + mg = 16N + (1kg)(9.8N/kg) = 25.8N,$$

in the upward direction.

You feel a stronger tension force in the string when the ball is at the bottom than when it is at the top. If v is small enough, then $mv^2/r = F_{net}$ could be smaller than $mg$, and $T_{top} = F_{net} - mg$ could be negative. This just means that instead of pulling the ball down, you have to push it up to keep it in uniform circular motion.

# Centripetal Forces Cont.

**Satellite:**

*Satellite A orbits the earth at a distance r from the earth's center, and satellite B orbits at a distance R from the earth's center. Given that r < R, which satellite moves at a greater speed? (If you haven't studied gravitation yet, the magnitude of the gravitational acceleration is equal to $GM/r^2$, where M is the earth's mass and G is a constant.)*

*(a) Satellite A*

*(b) Satellite B*

*(c) Both move at the same speed*

*(d) Unknowable without the mass of the earth*

**Solution:**

Here, the only relevant force on the satellites is the gravitational force from the earth.

$$\vec{F_{net}} = \vec{F_c} = \vec{F_g}.$$

Dividing by the satellite mass and taking magnitudes, we have

$$a_c = a_g$$

$$v_A{}^2/r = GM/r^2$$

$$v_A{}^2 = GM/r.$$

# Centripetal Forces Cont.

Similarly, $v_B^2 = GM/R$. Dividing the last two equations,

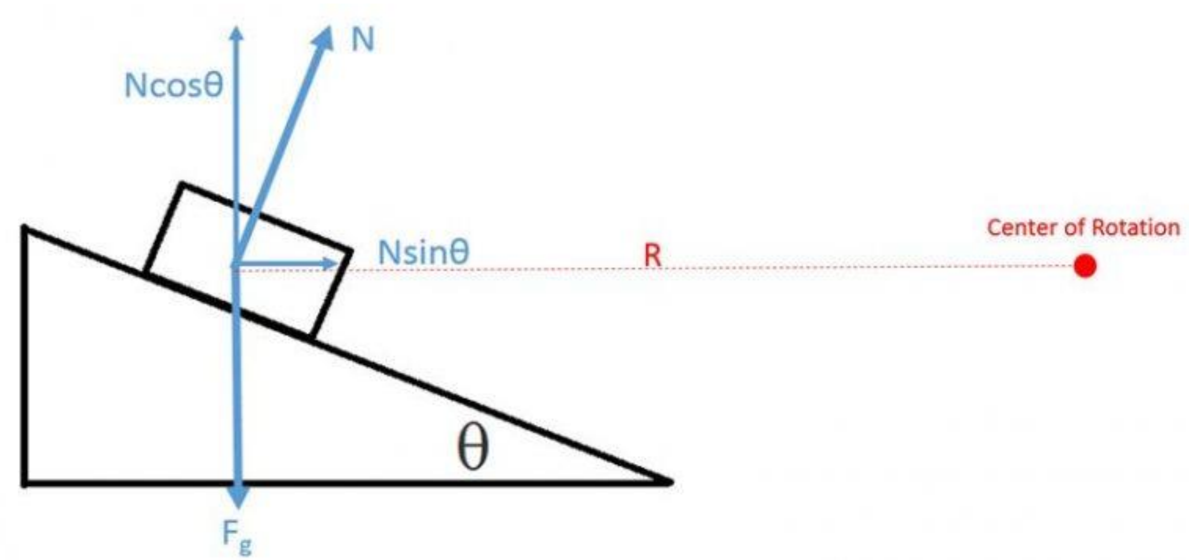
$$\frac{v_A}{v_B}^2 = R/r > 1.$$

Therefore, satellite A moves faster than satellite B. In general for gravitational orbits, the farther you are from the massive object being orbited, the slower you move.

**Car on a Ramp:**

A car makes a turn on a friction less, circular ramp of incline angle $\vartheta$. The distance from the car to its center of rotation is $R$, a constant. Find the car's speed, $v$. If the car accidentally came into the turn with a speed higher than $v$, how would $R$ change?

*Solution:* As always, draw a free-body diagram of the forces on the car. Often, physicists like to draw cars as rectangles.



# Centripetal Forces Cont.

The car stays at the same height on the ramp, so the center of rotation is actually at this height (the plane of rotation is as high as the car). The net, centripetal force must therefore point horizontally, because there is no vertical acceleration.

Resolving the forces in horizontal and vertical components, we find

$$F_{net,x} = F_c = Mv^2/R = N sin\theta$$

$$F_{net,y} = 0 = N cos\theta - Mg.$$

The y-equation yields $N = \frac{Mg}{cos\theta}$; substituting in the x-equation yields $Mv^2/R = (\frac{Mg}{cos\theta}) sin\theta$, or

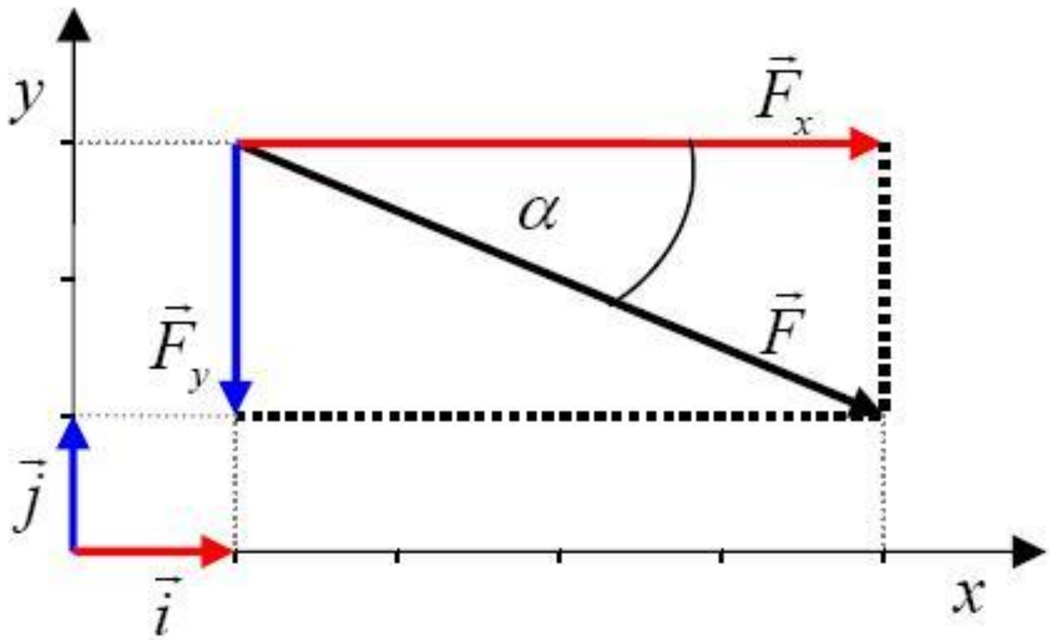
$$v = \sqrt{Rg tan\theta}.$$

If the car came into the curve with a speed greater than *v*, then *R* would increase: the car would move up the ramp. You can see this from the expression for v or use your intuition that when the centripetal force is not high enough to pull the car into a circular path, the car moves outside the circle rather than inside.

## Wrapping Up Centripetal Forces for AP Physics 1

For particles acted on by different forces, you could say this: the centripetal force is the tension in an imaginary string that would produce the same circular motion (same radius and speed) as the true forces do when added together. Centripetal forces always point towards the center of rotation and have magnitude $mv^2/r$. When solving a centripetal force problem on the AP Physics 1 exam, draw a free-body diagram with all true forces as vectors. Add these vectors up; the result is the centripetal force.

# Force Diagrams



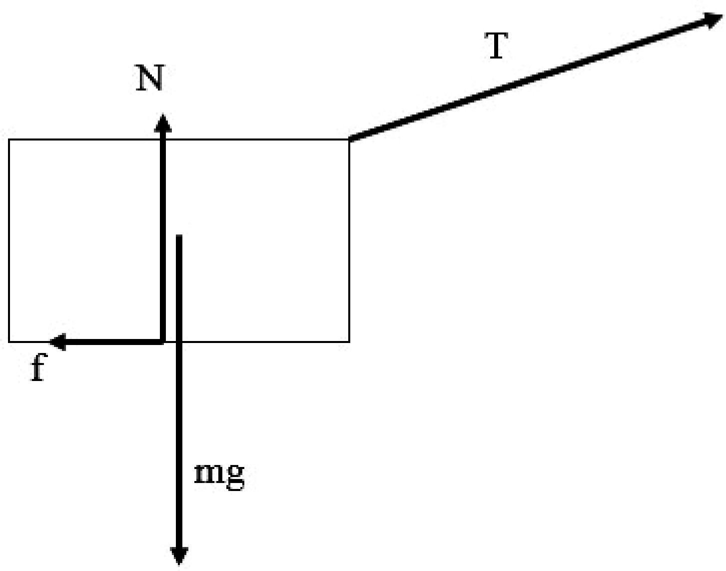

[Image Source: Wikimedia Commons]

A force diagram or free-body diagram is a schematic drawing of an object that includes the vector forces acting on that object. Drawing force diagrams makes it much easier to keep track of multiple force and to decompose forces into components. Drawing force diagrams is essential to scoring well on the AP Physics 1 & 2 Exams – doing so is often worth points on an FRQ about forces. In this AP Physics 1 & 2 Review, we review how to draw force diagrams and work some past FRQ questions.

# Force Diagrams Cont.

## Drawing Force Vectors

Here's a preview of a force diagram we'll analyze later:




As the diagram shows, there are four important characteristics of each force vector in a force diagram:

1. The length of the arrow on the diagram represents the strength of the force.

2. The arrow should point in the direction the force does.

3. The tail of the arrow should be drawn where the force acts on the object. This is important for questions about torque.

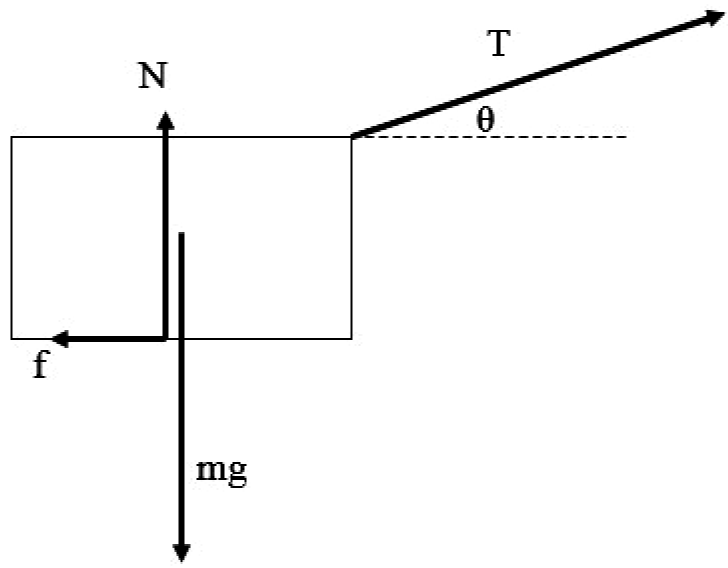
4. You should write the name of the force next to its arrow representation.

These characteristics are best understood through examples.

# Force Diagrams Cont.

**Box on the Floor**

*You pull on a string which is tied to the corner of a box at angle ϑ relative to the horizontal. The box accelerates horizontally, and friction is present. Draw the force diagram and explain its features.*




**Solution:**

You saw the diagram already – now we explain its features.

The box: In this case drawing the object is very easy, but more complex shapes can also be represented by a box or a circle in force diagrams. If there are multiple objects in the force diagram, label them for clarity.

Tension, T: The tension force has its tail at a corner of the box and points at angle ϑ above the horizontal.

Gravitational force, mg: The gravitational force acts at the center of the box and points straight down. This force will appear in most force diagrams that take place on Earth.

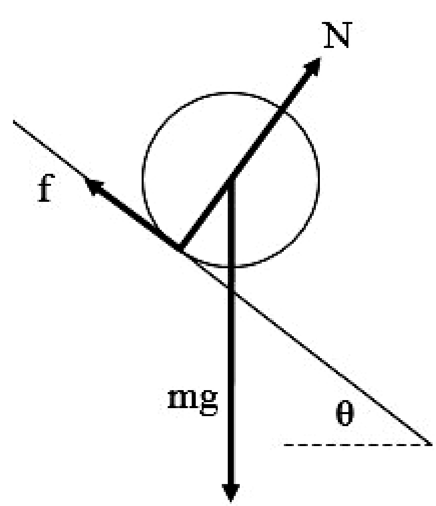
# Force Diagrams Cont.

Normal force, N: Since the normal force comes from the ground, its tail is located at the middle-bottom of the box (left of the gravitational force for clarity). The normal force is always perpendicular to the surface the object is resting upon, and points in the direction from the surface to the object. Since the box has no vertical acceleration, the normal force plus the vertical component of the tension should equal the gravitational force in magnitude – as they approximately do in the figure.

Frictional force, f: Friction always points opposite the direction of motion: the box moves right, so friction points left in the figure. Clearly, the friction acts at ground level, so we draw its tail at the middle-bottom of the box. The box accelerates to the right, so the horizontal component of tension must be greater than the friction, which is true in the figure.

**Ball on an Incline**

A solid ball rolls without slipping down an incline at angle θ above the horizontal. Draw the force diagram.



# Force Diagrams Cont.

**Solution:**

Gravitational force, mg: the gravitational force acts at the center of the ball and points straight down.

Normal force, N: the normal force points perpendicularly away from the incline and acts at the contact point between the ball and the incline. Since there is no acceleration perpendicular to the incline, N is equal in magnitude to the component of gravity perpendicular to the incline, $mg\cos\vartheta$.

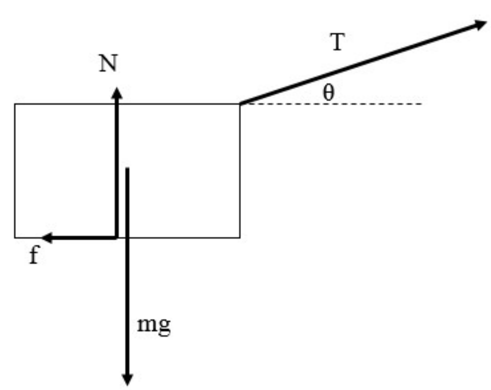
Frictional force, f: the frictional force points *up* the incline because only this force produces a torque. It tends to rotate the ball clockwise, as the ball must to roll *down* without slipping.

## Decomposing Force Vectors

The point of drawing these force diagrams is to make decomposing force vectors easier. Any two-dimensional vector can be written in terms of perpendicular components; the idea is to pick axes which lighten up the math. We'll see this in our second example.

**Box on the Floor, Part 2**

Resolve all the forces on the force diagram for "Box on the Floor" into horizontal and vertical components. If the box has horizontal acceleration a to the right, set up Newton's Second Law in the horizontal and vertical directions.



# Force Diagrams Cont.

**Solution:**

This problem is pretty easy – only one force is not purely vertical or horizontal. The tensile force can be resolved into

$$\vec{T} = T\cos\theta\hat{x} + T\sin\theta\hat{y}.$$

In the *x*-direction, the net force is *ma*.

$$ma = F_{net,x} = T\cos\theta - f.$$

There is no acceleration in the *y*-direction, and hence no net force.

$$0 = F_{net,x} = N + T\sin\theta - mg.$$

**Ball on an Incline, Part 2**

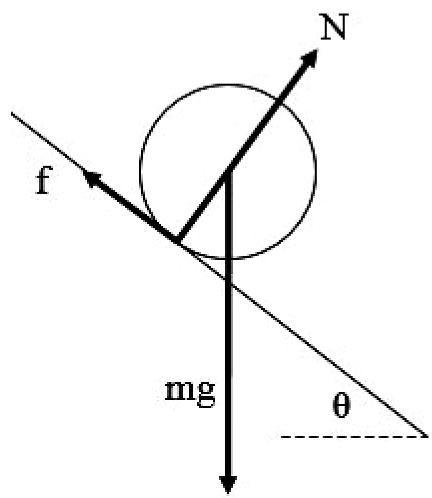
*Resolve the forces you drew for "Ball on an Incline" into:*

*(a) Horizontal and vertical components*

*(b) Components parallel and perpendicular to the incline*

# Force Diagrams Cont.

*If the ball has acceleration a down the incline, set up the equations of motion for both (a) and (b) above.*




**Solution:**

(a) The gravitational force is the only force that points purely horizontally or vertically. We resolve the other forces with angle chasing and trigonometry:

$$\vec{N} = N\sin\theta\hat{x} + N\cos\theta\hat{y}.$$

$$\vec{f} = -f\cos\theta\hat{x} + f\sin\theta\hat{y}.$$

The $cos\vartheta$ term in the decomposition of $f^{\rightarrow}$ is negative because the horizontal component of $f^{\rightarrow}$ points to the left, and the positive horizontal axis points to the right.

# Force Diagrams Cont.

Notice that in one case we used *cosϑ* to calculate the horizontal component and *sinϑ* to calculate the vertical component, but in another case we used *cosϑ* to calculate the vertical component and *sinϑ* to calculate the horizontal component. If you are ever unsure of which form to use, remember that the equation should work for any value of *ϑ*.

If *ϑ* = $0^o$ in our current example, the surface would be flat and the normal force would point straight up with no horizontal component. So when we substitute $0^o$ into our equation, we should get N for the vertical component and 0 for the horizontal component. The equation above fits this criteria, so we have confirmed that we made the correct choice.

We must also resolve the acceleration. It points down the incline (opposite the direction of the frictional force, f).

$$\vec{a} = a\cos\theta\hat{x} - a\sin\theta\hat{y}.$$

Newton's Second Law applied in the x- and y-directions yield

$$ma\cos\theta = F_{net,x} = N\sin\theta - f\cos\theta.$$

$$-ma\sin\theta = F_{net,y} = N\cos\theta + f\sin\theta - mg.$$

(b) We define the parallel direction $\hat{\|}$ to point down the incline (opposite the friction) and the perpendicular direction $\hat{\perp}$ to point away from the incline (in the same direction as the normal force).

We now have only one force to resolve: the gravitational force.

$$m\vec{g} = mg\sin\theta\hat{\|} - mg\cos\theta\hat{\perp}.$$

# Force Diagrams Cont.

The acceleration points purely in the parallel direction: $\vec{a} = a\hat{||}$. We can now write Newton's equations of motion:

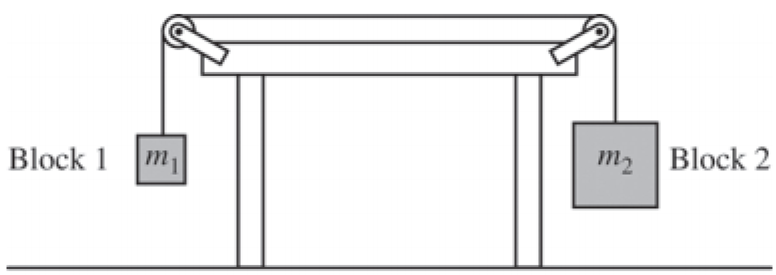
$$ma = F_{net,||} = mg \sin\theta - f.$$

$$0 = F_{net,\perp} = N - mg\cos\theta.$$

The second way of resolving the forces is superior. We only had to resolve one force instead of two, and we can now calculate the total acceleration and normal force directly. For example, the perpendicular equation of motion already tells us that $N = mg\cos\vartheta$.

**2015 AP Physics 1 FRQ 1**

*In the diagram below, the string is massless, the pulleys are frictionless, and $m_1 < m_2$. Draw free-body diagrams for blocks 1 and 2.*




Note: Figure not drawn to scale.

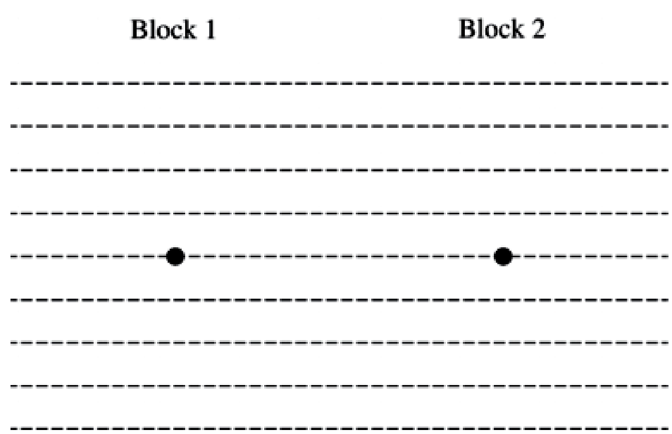
[Image Source: CollegeBoard]

# Force Diagrams Cont.

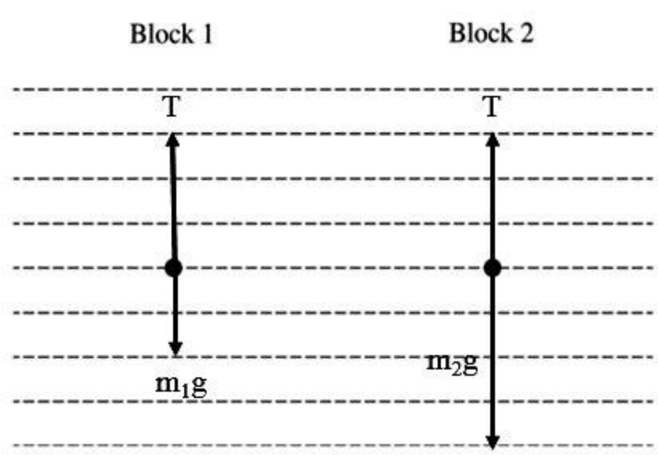
**Solution:**

The string is massless, so the tension in it is the same everywhere. (Otherwise there would be a nonzero force on some part of the string; since $m = 0$, then $F = ma = 0$ as well.)

Since $m_1 < m_2$, $m_2$ accelerates downward: the gravitational force on $m_2$ is larger than the string tension. The converse is true for $m_1$. The test gives you two dots which represent the two masses:




Taking the relative lengths of tension and the two gravitational forces into account, your finished drawings should look like this:



# Force Diagrams Cont.

The lengths of the tension vectors are the same on both masses because both have the same magnitude $m_2g$ is longer than $m_1g$ because its magnitude is larger.

## Wrapping Up Force Diagrams for AP Physics 1 and 2

**Three Important Characteristics of a Force Vector in a Force Diagram:**

1. The length of the arrow on the diagram represents the strength of the force.

2. The arrow should point in the direction the force does.

3. The tail of the arrow should be drawn where the force acts on the object. This is important for questions about torque.

4. You should write the name of the force next to its arrow representation.

**Decomposing Force Vectors**

We resolve force vectors into perpendicular components with trigonometry. A good choice of axes allows you to resolve fewer forces and simplifies Newton's equations of motion.

# Momentum Review

[Image Source: Flickr]

Roughly speaking, momentum is how difficult it is to stop a moving object. In AP Physics 1, you learn the algebraic definition of momentum, its relation to force and impulse, and the principle of momentum conservation in collisions. In this article, we'll review these topics and cover some example problems relevant to the AP Physics exams.

# Momentum Review Cont.

## The Algebraic Definition of Momentum

The more massive an object and the faster it moves, the harder it is to stop. For example, it takes more effort to stop a moving bowling ball than a marble moving at the same speed. These properties are encapsulated in the definition of momentum:

$$\vec{p} = m\vec{v},$$

where $\vec{p}$ is the momentum, $m$ is the mass, and $\vec{v}$ is the velocity.

As you can see, momentum is a vector and obeys the vector addition rules. For example, if mass 1 has momentum *3kg m/s* in the x-direction and mass 2 has momentum *4 kg m/s* in the y-direction, then the total momentum of both masses is $(3kgm/s)\hat{x} + (4kgm/s)\hat{y}$, which doesn't point in either the x- or y-directions.

## Force and the Impulse-Momentum Theorem

Newton's Second Law relates force and acceleration: $\vec{F} = m\vec{a}$.

Remember that the kinematic definition of acceleration is change in velocity per time:

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}.$$

If the mass of an object is constant, we may substitute this into Newton's Second Law, which gives

$$\vec{F} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}\Delta t = m\Delta\vec{v}.$$

# Momentum Review Cont.

$\vec{F}\Delta t$ is commonly called the *impulse* and is denoted by $\vec{J}$, and since $m\Delta\vec{v} = \Delta\vec{p}$, we have

$$\vec{J} = \Delta\vec{p}, \text{ where } \vec{J} = \vec{F}\Delta t.$$

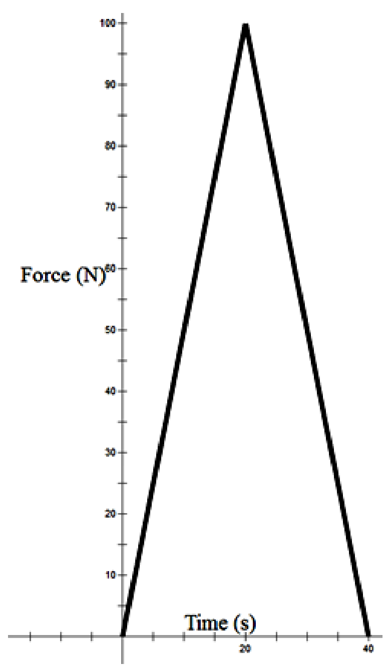
In words, Impulse = Change in Momentum.

This formula is powerful because it tells us the relation between force, time, and momentum – if you want to stop a moving ball in a shorter time, you must push harder, and the greater the momentum, the harder you must push! It is the algebraic statement of our physical intuition at the beginning of this article.

On the AP Physics 1 exam, you might see a graph of force vs. time and a question with a asking you to find the impulse:

**Plot of force vs. time.**

What is the impulse exerted by the force in the following diagram from 0 to 30 seconds?



# Momentum Review Cont.

**Solution:**

Remember that $J = F\Delta t$; however, force is not constant over time. We must find the area between the graph of F and the horizontal axis for the 30 second time interval required. To do so, we split this time interval into two parts:

*0 – 20 seconds.* The graph is a triangle with base 20 s and height 100 N, so the impulse is (20 s) (100 N) = 2000 N·s.

*20 – 30 seconds.* The graph is a trapezoid with base 10 s and average height (100 N + 50 N) / 2 = 75 N. The impulse is therefore (10 s)(75 N) = 750 N·s.

Our final answer is 2000 N·s + 750 N·s = 2750 N·s.

## Conservation of Momentum

Let's take another look at the impulse-momentum theorem:

$$\vec{F}\Delta t = \Delta\vec{p}.$$

If $\vec{F}$= 0, then {\Delta $\Delta\vec{p}$ = 0 as well, and momentum does not change. This is the essence of the principle of *conservation of momentum:*

> *If no net external force acts on a system, the total linear momentum of the system stays constant. In mathematical language, If $\vec{F}_{ext}$ = 0, then \Delta $\Delta\vec{p}$ = 0.*

Let's quickly review external vs. internal forces. Suppose you're studying a bunch of objects; these objects constitute the *system*. Forces between masses within the system are called *internal*, and forces between masses within the system and something outside the system are called *external*. We don't care about forces between masses which are both outside the system, because these forces don't change the system in any way.

# Momentum Review Cont.

If you have a bag full of clay balls floating in space. Forces between the balls, such as the forces in collisions, add to zero because any internal force from one mass on another mass in the system comes with an equal and opposite reaction force. The vector sum of these two forces is zero.

We now derive the principle of momentum conservation from Newton's Second and Third Laws.

Recall that the momentum of a particle of mass m and velocity $\vec{v}$ is $\vec{p} = m\vec{v}$. The total momentum of a system with different masses of different velocities is then $\vec{P} = \sum \vec{p} = \sum m\vec{v}$, where $\sum$ is the notation for summation.

We can make this idea rigorous with mathematics and Newton's Second Law, $\vec{F} = m\vec{a}$.

# Momentum Review Cont.

Here's the derivation.

Recall that *p=mv* and that acceleration is change in velocity per time:

$$\vec{F} = m\vec{a} = m\frac{\Delta\vec{v}}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t}.$$

The total momentum of a system is the sum of the momenta of its individual particles:

$$\vec{P} = \sum \vec{p}$$

Remember how I said internal forces come in equal and opposite pairs? This means that the sum of all internal forces is zero, because the sum of a bunch of zeros (one for each force pair) is zero. The sum of external forces can be nonzero because the equal and opposite reaction force to an external force does not act on the system. Therefore,

$$\vec{F_{net}} = \vec{F_{ext}} = \frac{\Delta\sum\vec{p}}{\Delta t}.$$

If $F_{ext} = 0$, then $\Delta \vec{p} = 0$, so momentum is constant.

## Collisions

The AP Physics 1 Exam will test your understanding of momentum conservation with collision problems. Here's one common FRQ type, which sometimes trips people up:

# Momentum Review Cont.

**Alice and Bob Collide**

*Alice and Bob are ice-skating and accidentally bump into each other. Alice comes out of the collision with a speed five times that of Bob's. Who experienced the greater impulse?*

**Solution:**

Let the system consist of only Alice and Bob. There are no external forces in the horizontal plane; the normal and gravitational forces sum to zero in the vertical direction. Therefore, $F_{net} = 0$ and total momentum is conserved.

Since impulse = change in momentum = 0, Alice and Bob must have exerted equal and opposite impulses on each other. (Otherwise, the total impulse would not be zero.) Therefore, both impulses were of the same magnitude.

The AP Physics 1 exam typically tests only simple two-body collisions, so here's some vocabulary to describe the different types:

- An *elastic* collision is a collision in which both kinetic energy and momentum are conserved.

- An *inelastic* collision is a collision in which only momentum is conserved. The kinetic energy after the collision is less than the kinetic energy before the collision; the difference is usually dissipated into heat or sound energy.

- A *completely inelastic* collision is an elastic collision in which the two bodies move together after the collision. Completely inelastic collisions dissipate the most energy.

In reality, no collisions are completely elastic. For example, billiard ball collisions involve energy loss to sound.

# Momentum Review Cont.

Here's a completely inelastic collision problem:

**Alice and Bob make up**

*Bob slides on friction-less ice at speed v, but he hasn't lost any weight. Alice decides she misses Bob, so she lands vertically on Bob from a helicopter. (She hugs him, too!) After the collision, what is the speed of the couple?*

*(a) 8v*

*(b) v/8*

*(c) v/9*

*(d) 8v/9*

**Solution:**

Since Alice lands vertically, she exerts no horizontal force, so the x-component of momentum is conserved. Note that after the collision, Alice and Bob move as one mass:

$$P_o = P_f$$

$$m_B v = (m_A + m_B)\, v_f$$

$$v_f = m_B v / (m_A + m_B) = 8v/9.$$

The answer is (d). You might notice that Bob's speed didn't change much – the lighter the additional mass, the less difference it makes in the final speed.
Now for the final part: we solve the one-dimensional two-body *elastic* collision problem. We'll save you some pain by solving the equations for you and then you'll take a limiting case to show how physical results spring from the mathematics.

# Momentum Review Cont.

**The Classic Elastic Collision**

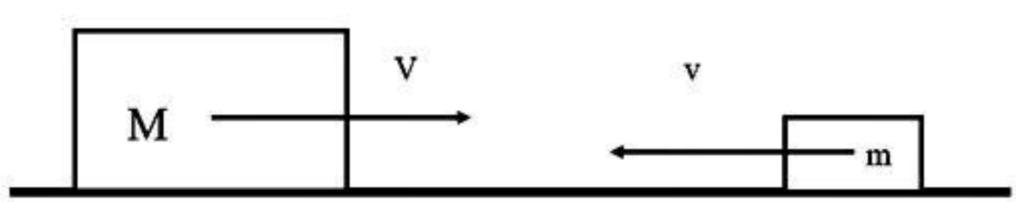
*A body of mass M and velocity V collides head-on and perfectly elastically with another body of mass m and velocity v. After the collision, the velocities of M and m are U and u, respectively.*

(a) Set up a system of equations to solve for the final velocities, U and u. Do not solve this system; its solutions are given below:

$$U = 2(MV + mv)/(M + m) - V$$

$$u = 2(MV + mv)/(M + m) - v.$$

(b) Reduce the given solutions for U and u to simpler forms for the case $M \gg m$ ($M$ is much greater than $m$). Comment on the result for $U$.




**Solution:**

Since this collision is elastic, both momentum and kinetic energy are conserved. Let $U$ and $u$ be the velocities of $M$ and $m$ after the collision:

(a) Momentum conservation: $MV + mv = MU + mu$

(b) Energy conservation: $\frac{1}{2}MV^2 + \frac{1}{2}mv^2 = \frac{1}{2}MU^2 + \frac{1}{2}mu^2.$

# Momentum Review Cont.

We have two equations and two unknowns ($U$ and $u$), so we can solve this system for $U$ and $u$. Warning: this is complicated and you would not be required to solve such a system on the AP Physics 1 exam. You might have noticed that the energy equation involves squared variables, so you can't use the usual method of solving two linear equations. I won't write the steps out, but to solve this system, we rearrange the first equation to find $U$ in terms of $u$ (or $u$ in terms of $U$) and substitute that result in the second equation. We then either factor the quadratic or employ the quadratic formula, which yields

$$U = 2(MV + mv)/(M + m) - V$$

$$u = 2(MV + mv)/(M + m) - v.$$

(b) If $M \gg m$, then $mv$ is small compared to $MV$ and $m$ is small compared to $M$. We may therefore approximate $(MV + mv) / (M + m) \approx (MV) / (M) = V$. Substituting,

$$U = 2V - V = V,$$

$$u = 2V - v.$$

Since $U = V$, the velocity of the large mass did not change – the large mass was so much larger than the small one that the collision had almost no effect on the velocity of the large mass.

# Momentum Review Cont.

## Wrapping up Momentum for the AP Physics 1 Exam

Here are the basic equations and definitions you need for the AP Physics 1 Exam.

- *Definition of momentum:* $\vec{p} = m\vec{v}$
- *Impulse – momentum theorem:* $\vec{J} = \Delta\vec{p}$

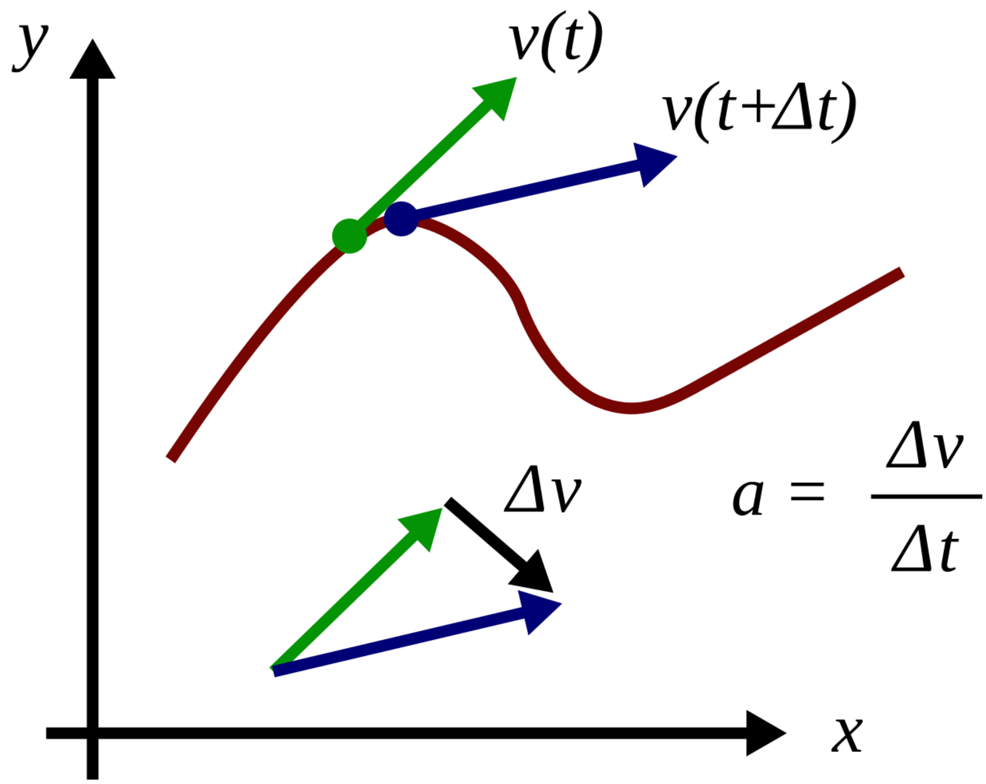
Conservation of momentum:

- If no net external force acts on a system, the total linear momentum of the system stays constant. In mathematical language, If $\vec{F}_{ext} = 0$, then $\Delta\vec{p} = 0$.

Types of collisions:

- An *elastic* collision is a collision in which both kinetic energy and momentum are conserved.
- An *inelastic* collision is a collision in which only momentum is conserved. The kinetic energy after the collision is less than the kinetic energy before the collision; the difference is usually dissipated into heat or sound energy.
- A *completely inelastic* collision is an elastic collision in which the two bodies move together after the collision. Completely inelastic collisions dissipate the most energy.

# Acceleration




[*Image Source: Wikimedia Commons*]

Acceleration is a word that you've probably heard and used quite often throughout your life, usually when referring to racing. However, what exactly is acceleration and how will it be used on an AP Physics exam? In physical terms, acceleration is defined as the change in velocity over the change in time. It is a step up from velocity in that velocity is the change in position over time. It is officially defined as such:

$$a \equiv \frac{\Delta v}{\Delta t}$$

v refers to the velocity of the object, t refers to time, and a is the acceleration.

# Acceleration Cont.

This notation is standard; you'll rarely find any other letters or symbols to replace these variables. In addition to velocity and distance, acceleration is also a vector, meaning that it has both a magnitude and direction.

Because acceleration is a vector quantity, you can also have negative acceleration. Negative acceleration means that the object is slowing its velocity. The initial velocity is faster than its final velocity, so the object is slowing down, thus indicating a negative acceleration.

You may be tempted to use the word "deceleration" to describe negative acceleration. However, this term is more colloquial than scientific, for reasons we will not cover due to its irrelevance to the AP exam. However, when describing negative acceleration in a scientific context or for any CollegeBoard exam, use negative acceleration and not deceleration. Now let's proceed with this AP Physics Crash Course Review.

## Acceleration Case Study: 0-60

A common reference to acceleration that is found in vehicle specifications is called "0-60." You'll perhaps hear people ask, "What's the 0-60 on this car?" This question refers to how fast a car can accelerate from a standstill to 60 miles per hour (mph). This number is usually reported as a time, but you can always take 60 and divide it by that number to get the acceleration. This usually indicates how well a car speeds up.

For the sake of the AP exam, which will use SI units, we will pretend that 60 represents 60 meters per second (m/s) rather than mph. 60 m/s is approximately 135 mph. If a car goes 0-60 in 10 seconds, let's calculate its acceleration. To do so, we will first expand the above formula as such:

$$\Delta a \equiv \frac{v_f - v_0}{t_f - t_0}$$

$v_f$ refers to the final velocity, and $v_0$ refers to the initial velocity, while $t_f$ refers to the final time and $t_0$ is the initial time.

# Acceleration Cont.

In this case, we will call the starting point $t_0$ = 0 seconds (s). Because we're measuring the time over 10 seconds, $t_f$ = 10 s. When looking at the velocity, because we're starting at a standstill, the initial velocity is zero ($v_0$= 0 m/s) and the final velocity is 60 m/s ($v_f$ = 60 m/s). Let's plug in the numbers and see what we get.

$$\Delta a \equiv \frac{60m/s - 0m/s}{10s - 0s} = \frac{60m/s}{10s} = 6m/s^2$$

The acceleration of the car, in this case, is 6 m/s$^2$. Note the units. The seconds are squared in the denominator because we are taking the time difference of a quantity that has already considered a time difference.

What is the physical meaning of this quantity then? 6 m/s$^2$ means that over this 10-second interval, the velocity changed at an average of 6 meters between each second. So between t=0 s and t=1 s, acceleration changed at an average of 6 m/s. Between t = 1 s and t = 2 s, it changed at an average of 6 m/s, and so on.

It is possible to calculate the instantaneous acceleration at a given time point. However, that requires differential calculus, a topic that is beyond the scope of AP Physics 1 & 2, and is something you will go on to study should you proceed to AP Physics C.

### Gravitational Acceleration: A Special Case

Next in this AP Physics Crash Course Review is the special case of gravitational acceleration. Gravitational acceleration is the acceleration of objects due to the pull of gravity. Gravitational acceleration is a constant number recorded by Sir Isaac Newton and denoted by the letter *g*. Note that this constant is only on the surface of the earth. Each object has its own gravitational pull and therefore has a different strength. $g$ = 9.81 m/s$^2$, but most people generally record it as just $g$ = 9.8 m/s$^2$. It holds the same properties as normal acceleration, but gravitational acceleration is a specific case because it is fixed.

# Acceleration Cont.

Before we proceed any further with this example, we need to clear one thing up. Just like any acceleration, gravitational acceleration is a vector. Generally, we set our reference so that the ground is zero, with anything upward being positive in direction and anything going downward negative in direction. Therefore, you'll often see *g* written as –9.81 m/s$^2$ because gravity acts downward in this general reference state. Don't forget the negative; you could otherwise end up unnecessarily wasting a lot of valuable time.

For the sake of clarity, we're going to take the above example of a car and modify it so that you can see how gravitational acceleration works. Let's pretend that it's 20 years later, and that car has become nothing more than an obsolete piece of scrap. You take it to the scrapyard, say your goodbyes, wipe your tears, and leave on your hover board.

To scrap the car, a crane picks the car up from your drop-off point and drops it into the scrapyard. Let's say that it takes 10 s for the car to hit the ground. What is the velocity with which it hits the ground if we neglect any drag? Let's set up the same equation as above, just modified slightly.

$$g = \frac{v_f - v_0}{\Delta t}$$

Notice that we replaced *a* with *g.* As mentioned previously, *g* is just a special case of *a*, so it has the same units. Only gravitational acceleration is present; the car is scrap, and nobody is pressing on the gas pedal. Therefore, acceleration due to gravity is the only acceleration.

In addition, we just condensed the difference in time to its delta form, because we're given the change, which is the only thing that matters. We need to keep the change in velocity in its expanded form because we know the initial velocity (0 m/s because it's being dropped by the crane from a standstill) but not the final. Using algebra, let's rearrange the equation to solve for the final velocity.

$$-\Delta t + v_0 = v_f$$

# Acceleration Cont.

We multiplied the entire equation by the time difference to remove it from the denominator. We then added the initial velocity to the other side of the equation to isolate the term we want to solve for, which is the final velocity. However, we know that $v_0 = 0$ m/s, so we can remove the term entirely. In addition, *g* acts downward, hence the negative, which gives us the following.

$$v_f = g\Delta t = (-9.8m/s^2)(10s) = -98m/s$$

Now, 98 m/s is obviously extremely fast (approximately 220 mph). That is because the time interval we gave was extremely high, which would mean that the car would have had to have been dropped from a high height. However, we kept the time interval the same to show you how to manipulate this equation and use it with gravitational acceleration.

Actually, while we're on the topic, why not calculate the height from which this car was dropped? We just calculated the final velocity, which means we have the change in velocity, and we have the time difference. So let's set up the velocity equation.

$$\Delta v = \frac{y_f - y_0}{\Delta t}$$

We set up the velocity equation in the same format that we did the previous acceleration equation because of what information we have. One quick note: you're probably used to seeing *x* to represent position and distance. That's because so far, you've probably only done one-dimensional velocity and acceleration.

When you start doing two-dimensional calculations, vertical distance will become a factor, and this is usually denoted by *y*. Because our example deals with vertical distance, we are going to use *y* so you get used to this notation. Now, let's set the ground to be $y_f = 0$ m, because it's our reference point.

# Acceleration Cont.

Now, the problems that CollegeBoard will give you will not be presented as straightforward as they are in this AP Physics Crash Course Review. However, they are still as simple. Read between the lines, and you will find out that the acceleration problems they give you where an object either speeds up or slows down will fall into one of the two categories presented above: horizontal acceleration or gravitational acceleration.

# Conservation Laws

Conservation laws dictate that some quantity which describes a system stays constant over time, regardless of any changes in that system. Five of these laws are covered in AP Physics 1 and 2: the conservation of mass, charge, momentum, angular momentum, and energy. In this AP Physics 1 & 2 Review, we'll describe these laws, when they are true, and how to apply them to multiple choice and FRQ questions.

### The Idea of a "System" and Internal Versus External Quantities

In physics, the "system" is the part of the universe being studied. For example, in an orbit problem about the earth and sun, the system consists of only the earth and the sun. The gravitational forces between the earth and sun are considered *internal* to the system because they act between two objects within the system. If an asteroid crashes into the earth, then the force of its impact is *external* to the system since the asteroid wasn't part of the system to begin with.

If you're studying a rolling ball, then the system is merely the ball and does not include the floor or the earth. The forces and torques on the ball are *external* to the system, because the floor and earth, which exert these forces and torques on the ball, are outside the system. Any forces between the atoms of the ball itself are *internal* because all of the ball's atoms are part of the system.

Now that you know about systems and the difference between external and internal quantities, here's the general form of a conservation law:

If no net external ______ acts on or moves into a system, the total <u>conserved quantity</u> stays constant over time.

For ease of reference, we'll keep this form when stating each conservation law.

# Conservation Laws Cont.

## Conservation of Mass

If no net mass leaves or enters a system, the total mass of the system stays constant.

Imagine several masses of clay moving inside a large bag. Mass conservation means that whatever the masses do inside a system (collide, rub together, or break apart), their sum is always the same, as long as no net mass leaves or enters.

I say no *net* mass leaves or enters because mass is still conserved if mass exchange occurs at opposite and equal rates over the boundary of a system. Imagine a flowing river: as long as the input from its tributaries equals the output to the ocean, the total mass of the river water is constant. (This is the basis of the *continuity equation* in fluid dynamics.)

It might seem silly, but mass conservation is a necessary law because it tells us that *masses add.* This is trickier than it seems – if masses multiplied, for instance, then a 2kg ball colliding with a 5kg ball would produce a 10kg ball, and mass wouldn't be conserved anymore!

## Conservation of Charge

If no net charge leaves or enters a system, the total charge of the system stays constant.

Similar to mass conservation, charge conservation tells us that charges add – if you add 2C of charge to a ball of charge -8C, you'll end up with a ball of charge -6C.

Let's return to the river analogy in the previous section:

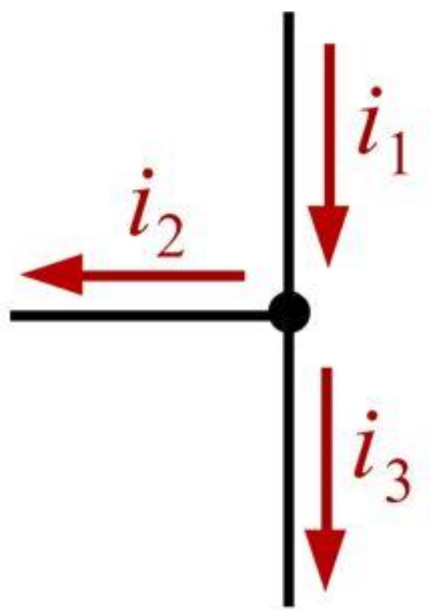
*Water flow in = Water flow out.*

# Conservation Laws Cont.

As you know, there are electric currents as well as water currents! *Nodes* are places in electrical circuits where different wires meet. To prevent buildup of excess charge, we require that at any node,

*Current in = Current out.*

In the picture of a circuit node below, we must have $i_1 = i_2 + i_3$.




This is called Kirchhoff's junction rule, or sometimes Kirchhoff's node rule. As you can see, it really is just a result of the conservation of charge.

# Conservation Laws Cont.

## Conservation of Linear Momentum

If no net external force acts on a system, the total linear momentum of the system stays constant.

Recall that the momentum of a particle of mass m and velocity $\vec{v}$ is $\vec{p} = m\vec{v}$. The total momentum of a system with different masses of different velocities is then $\vec{P} = \sum \vec{p} = \sum m\vec{v}$, where $\sum$ is the notation for summation.

If you have a bag full of clay balls floating in space, then there is no net external force, and the total momentum of the balls is conserved. It matters not if the balls hit each other because any internal force from one mass on another mass in the system comes with an equal and opposite reaction force. The vector sum of these two forces is zero.

We can make this idea rigorous with mathematics and Newton's Second Law, $\vec{F} = m\vec{a}$. Here's the derivation.

Recall that $p = mv$ and that acceleration is change in velocity per time:

$$\vec{F} = m\vec{a} = m\frac{\Delta\vec{v}}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t}.$$

The total momentum of a system is the sum of the momenta of its individual particles:

$$\vec{P} = \sum \vec{p}$$

Remember how I said internal forces come in equal and opposite pairs? This means that the sum of all internal forces is zero, because the sum of a bunch of zeros (one for each force pair) is zero.

# Conservation Laws Cont.

The sum of external forces can be nonzero because the equal and opposite reaction force to an external force does not act on the system. Therefore,

$$\vec{F_{net}} = \vec{F_{ext}} = \frac{\Delta \sum \vec{p}}{\Delta t}.$$

If $F_{ext}$=0, then $\Delta \vec{p}$ = 0, so momentum is constant. Here are two illustrative example problems, similar to what you would see on the AP Physics 1 Exam. Remember that only *external* forces change the momentum of a system.

**Alice and Bob break up**

*Alice and Bob stand still on friction less ice. After Alice discovers that Bob is 8 times as massive as she is, she pushes him away. If Bob's speed is v, what is Alice's speed?*

*(a) 8v*

*(b) v/8*

*(c) 9v*

*(d) v/9*

**Solution:**

Let the system consist of both Alice and Bob, and let Bob move in the positive x-direction. There are two opposite and equal *internal* forces here: Alice pushes on Bob, and by Newton's third law, Bob pushes back on Alice. However, the ice is frictionless, so there is no external force, and momentum is conserved.

# Conservation Laws Cont.

Since the system had no initial momentum,

$$P_o = P_f$$

$$o = m_A v_A + m_B v_B$$

$$v_A = -\left(m_B/m_A\right) v_B$$

We know that $m_B/m_A$ = 8, so Alice moves eight times as fast, and the answer is (a). The negative sign signifies that Alice moves in the negative x-direction.

**Alice and Bob make up**

*Bob slides on frictionless ice at speed v, but he hasn't lost any weight. Alice decides she misses Bob, so she lands vertically on Bob from a helicopter. (She hugs him, too!) After the collision, what is the speed of the couple?*

*(a) 8v*

*(b) v/8*

*(c) v/9*

*(d) 8v/9*

**Solution:**

Since Alice lands vertically, she exerts no horizontal force, so the x-component of momentum is conserved. Note that after the collision, Alice and Bob move as one mass:

$$P_o = P_f \; m_B v = \left(m_A + m_B\right) v_f \; v_f = m_B v / \left(m_A + m_B\right) = 8v/9.$$

# Conservation Laws Cont.

The answer is (d). You might notice that Bob's speed didn't change much – the lighter the additional mass, the less difference it makes in the final speed.

## Conservation of Angular Momentum

If no net external torque acts on a system, the total momentum of the system stays constant.

First, some reminders:

Recall that the torque about some rotational axis is where $\theta$ is the angle between $\vec{r}$ and $\vec{F}$. Also, the angular momentum vector is the product of the moment of inertia and the angular velocity vector: $L = I\omega$. The moment of inertia of a mass *m* a distance *r* away from the axis of rotation is

Fortunately, conservation of angular momentum is almost exactly the same as conservation of linear momentum! Just replace each linear quantity with its corresponding rotational analogue:

| Linear Quantity | Rotational Quantity |
|---|---|
| Distance, $x$ | Angle, $\vartheta$ |
| Mass, $m$ | Moment of inertia, $I$ |
| Speed, $v$ | Angular speed, $\omega$ |
| Momentum, $p$ | Angular momentum, $L$ |
| Force, $F$ | Torque, $\tau$ |

If $\tau_{ext}$= 0, then $L$ *system* is constant. Note that just as $p = mv$, $L = I\omega$.

# Conservation Laws Cont.

Let's do some AP-style practice questions. Remember that although an external force $\vec{F}$ may be present, it must make a nonzero angle with $\vec{r}$ in order for the torque, $\tau = rF \sin\vartheta$, to be nonzero.

**Satellite**

*A satellite orbits the earth at a constant distance from the earth's center. Explain why its angular momentum is constant.*

**Solution:**

Let the origin be the center of the earth, and let the satellite be at position $\vec{r}$ relative to this origin. The axis of rotation passes through the center of the earth, so the gravitational force and position vector are antiparallel: the gravitational force points from the satellite to the earth, and the position vector points from the earth to the satellite. Therefore, $\vartheta = 180^o$ and $\sin\vartheta = 0$; since the gravitational force is the sole force acting on the satellite, there is no net torque and angular momentum is conserved.

**Two discs**

*Two discs are constrained to move on a vertical axis. The top disc has zero initial angular speed and falls, sticking to the bottom disc, which has angular speed ω. If the top disc has moment of inertia II and the bottom disc has moment of inertia 2I2I, what is their final angular speed?*

(a) $3\omega$

(b) $2\omega$

(c) $2\omega/3$

(d) $\omega/3$

# Conservation Laws Cont.

**Solution:**

There is no external torque, so angular momentum is conserved. Since $L = I\omega$,

$$L_o = L_f$$

$$2I\omega = (I + 2I)\,\omega_f$$

$$\omega_f = 2\omega/3$$

The correct answer is c. The linear analogue to this rotational problem is a collision between a particle of mass *m* and speed *v* and a stationary particle of mass *2m*.

## Conservation of Energy

If no non-conservative force acts on a system, the total mechanical energy of the system stays constant.

Loosely speaking, energy is the ability to do work. You might recall that the kinetic energy of a particle of mass m and speed $v$ is $K = \frac{1}{2}mv^2$, and that the change in potential energy due to a force acting over a distance is $\Delta U = -F\Delta x$. Total (or mechanical) energy is defined as the sum of the kinetic and potential energies: $E = K + U$.

For AP Physics 1 and 2, the only non-conservative forces are dissipative frictional forces, such as kinetic friction between a block and an incline, and air drag on a parachute. Conservation of energy states that as long as these forces are absent, then *E* is constant.

# Conservation Laws Cont.

An interesting fact is that conservation of energy is really just another form of $\vec{F} = m\vec{a}$, without vectors. Using energy conservation and $\vec{F} = m\vec{a}$ on the same problem should yield the same answer, but energy is typically easier to use than $\vec{F} = m\vec{a}$, when applicable. Look for systems that have *no kinetic friction or drag forces*, and energy conservation may solve the problem.

**Block on an Incline**

*A block of slides from rest a vertical distance h down a friction less incline. Find its speed at the bottom.*

**Solution:**

There are no dissipative forces, so total energy is conserved. Since $E = K + U$,

$$K_o + U_o = K_f + U_f.$$

Taking the potential energy at the bottom to be zero, we have $U_f = O$ and $U_o = mgh$. The block is initially at rest, so $K_o = 0$, where $v$ is the speed at the bottom. Substituting,

$$\tfrac{1}{2}mv^2 = mgh$$

$$v = \sqrt{2gh}$$

This is a well-known result and is independent of the block's mass as well as the angle of inclination. You should be familiar with it for the AP Physics exams.

# Conservation Laws Cont.

**Wrapping Up Conservation Laws for AP Physics 1 and 2**

Remember that all conservation laws come in this form:

If no net external ______ acts on or moves into a system, the total conserved quantity stays constant over time.

There are conservation laws for mass, charge, momentum, angular momentum, and energy. Recognizing when and how to use these laws are vital to doing well on the AP Physics 1 and 2 exams.

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# Gravitational Potential Energy

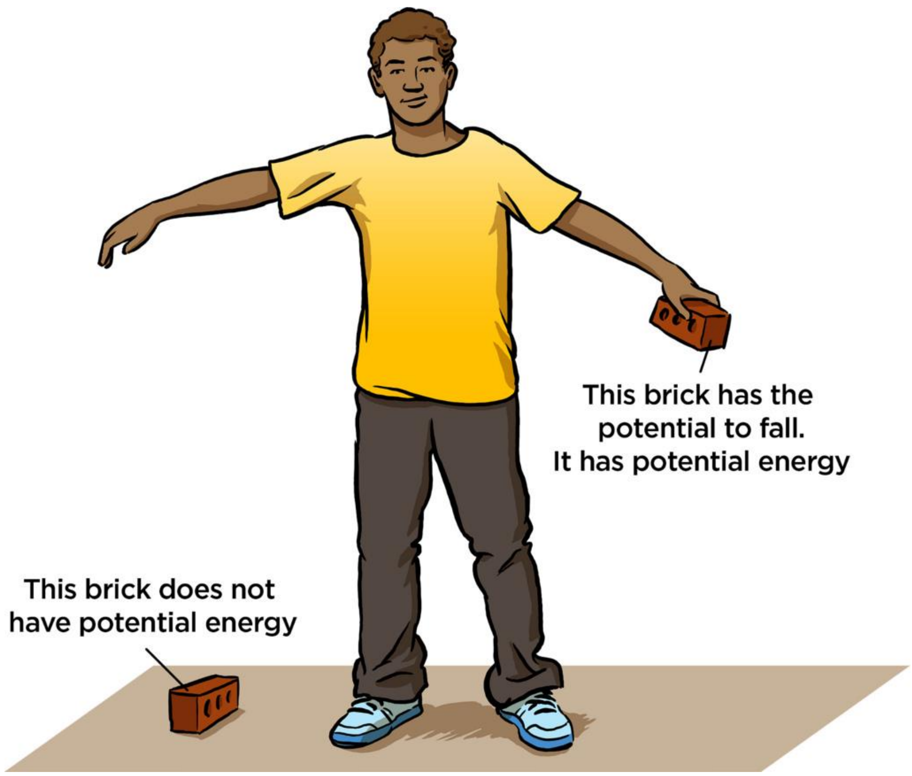



*Image Source: Flickr*

By this point in your study of physics, you should be familiar with acceleration due to gravity, forces, and the basics of energy. If not, go back and review these concepts in detail before reading this article. As most topics do in AP Physics, gravitational potential energy (GPE) builds off of previous ideas. If you don't have a firm grasp of the above concepts, you WILL be lost when exploring the rest of this theory. Having said that, once you have a solid understanding of the foundational topics, gravitational potential energy is a pretty straight-forward concept to learn.

# Gravitational Potential Energy Cont.

In this AP Physics crash course, we will explore gravitational potential energy, what it is, and why it's important. After defining GPE, we'll derive the formula to calculate it, work through an example, and explain how GPE fits in with the Work-Energy Theorem. Most importantly, we'll look at how this concept relates to the questions you'll be asked on the AP Physics 1 & 2 Exam.

## Understanding Gravitational Potential Energy

Gravitational potential energy is a type of potential energy. Essentially, GPE is the energy that a system has on an object due to the object's positioning within its respective gravitational field. It is important to note that the object itself doesn't have potential energy. Instead, it is the system that holds the potential energy due to the interactions between objects within the system.

The gravitational potential energy of a system physically refers to the potential energy that can be created through movement of that object through the system as a result of acceleration due to gravity. In essence, if the object is still, it refers to the total amount of work that can be extracted from that particular system.

Note that it is common practice to assign the lower bound of the system, usually the ground, as the spot where there is no potential energy. This is because, at the ground, the normal force upward from the surface of the ground counteracts the force of gravity pulling down on the object. Therefore, the object doesn't move and doesn't have any potential energy because the sum of the forces is zero. If the net force is zero, then the energy is zero because energy is defined as a force multiplied by a distance.

Also, gravitational potential energy only applies to systems that have a vertical component because gravity only acts in that direction. Now, that doesn't mean that ALL potential energies only act on the vertical axis. There is a spring potential energy that could also act on the horizontal axis should a spring be pointed in that direction. However, gravity physically cannot act in the horizontal direction.

# Gravitational Potential Energy Cont.

## Deriving the Formula for Gravitational Potential Energy

With these principles in mind, let's try and figure out a formula for gravitational potential energy. We know that energy is a force multiplied by a distance. Also, we know that a force is a mass multiplied by an acceleration. In this case, because we're dealing with gravity, the acceleration term would be due to gravity, or $g = 9.8\ m/s^2$. The mass refers to the mass of the object in question within the system.

So, we have a mass and an acceleration. That means we have the force component of the energy. We're still missing a distance. Because we're dealing with a vertical plane, we will call the distance the height. The height refers to how high the object is from the ground, or the point of zero potential energy. Here is the formula for potential energy.

$$PE_g = mgh$$

$PE_g$ refers to the gravitational potential energy. You may see other letters denote gravitational potential energy, such as $U$, but we will stick with $PE_g$. $m$ is the mass of the object, $g$ is the acceleration due to gravity, and $h$ is the height from the ground.

Remember that energy is a scalar quantity because it is the dot product of two vectors, force and distance. The physical definition of energy is the capacity to do work. You cannot have a negative capacity to do work. Either work is done, or it is not.

In other words, energy is the magnitude of the total amount of work that can be done within a system. Energy says how much of that work is possible, making it a scalar quantity. Therefore, it is important to note that because energy is a scalar quantity, g, in this case, will not be negative. This also explains why you can't have a negative height. Both of these statements are assuming the standard reference state with the ground being zero potential energy.

# Gravitational Potential Energy Cont.

## Example of Gravitational Potential Energy

Using the formula we just derived, let's look at a numerical example of gravitational potential energy so that you can understand it better. Let's say there are two boys holding identical tennis balls just above their heads. The tennis balls both have a mass of 0.3 kg. The first boy is 1.55 m tall, and the second boy is 1.60 m tall. Which system has more potential energy? Let's plug in and solve.

$$PE_{(g,1)} = mgh_1 = (0.3kg)(9.8m/s^2)(1.55m) = 4.6J$$

$$PE_{(g,2)} = mgh_2 = (0.3kg)(9.8m/s^2)(1.60m) = 4.7J$$

The taller boy has the ball in the system with more potential energy. As we mentioned before, the greater the height of the object, the more potential energy in the system. This is because the object has more space to fall, giving it the ability to hit the ground at a higher speed or with greater kinetic energy.

## Brief Overview of Kinetic Energy and Work-Energy Theorem

Kinetic energy is not the topic of this article, and neither is the Work-Energy Theorem. However, we'll briefly discuss both to help you wrap your head around what's going on with gravitational potential energy. We suggest that you look at our blog articles for both of these topics to gain a more thorough understanding because, as we'll see soon, aside from conceptual multiple-choice questions, you will rarely see a question on the AP Physics 1 & 2 exams that deals only with kinetic or potential energy. These two concepts are usually intertwined through the Work-Energy Theorem.

Kinetic energy is analogous to gravitational potential energy in that it shows how much energy is in the system. However, unlike gravitational potential energy where the object is still, kinetic energy implies motion because the velocity is included in its calculation.

# Gravitational Potential Energy Cont.

## Example of Gravitational Potential Energy

Using the formula we just derived, let's look at a numerical example of gravitational potential energy so that you can understand it better. Let's say there are two boys holding identical tennis balls just above their heads. The tennis balls both have a mass of 0.3 kg. The first boy is 1.55 m tall, and the second boy is 1.60 m tall. Which system has more potential energy? Let's plug in and solve.

$$PE_{(g,1)} = mgh_1 = (0.3kg)(9.8m/s^2)(1.55m) = 4.6J$$

$$PE_{(g,2)} = mgh_2 = (0.3kg)(9.8m/s^2)(1.60m) = 4.7J$$

As the object is dropped and falls toward the ground, the height decreases and the velocity increases, shifting the energy from potential into kinetic. Energy can neither be created nor lost in this system, so the total energy of the system stays the same. This means that all the energy that was potential is turning into kinetic. That is the Work-Energy Theorem.

The total work in the system is the sum of all potential and kinetic energies within it. Because no energy is lost in a system, the work done is zero, meaning that the energies will equal one another and the overall total energy is constant.

For the sake of completeness, we will also mention that the Work-Energy Theorem includes internal microscopic energy. However, that is way beyond the scope of this course and exam and is a topic that is covered in an upper-university level Physical Chemistry or Quantum Mechanics course. For the AP Physics 1 & 2 exam, and even for AP Physics C, you can assume that internal microscopic energy is negligible.

## Gravitational Potential Energy and the AP Physics 1 & 2 Exam

Now, on the AP Physics 1 & 2 exam, gravitational potential energy problems will NOT be as straightforward as the above problem was.

# Gravitational Potential Energy Cont.

That example was just to give you the general idea of what gravitational potential energy is. If you do get a question on gravitational potential energy, it will likely be early on in the multiple-choice section where you're going to have to estimate an energy given numbers because you won't have a calculator.

Also, you will probably be asked a conceptual question on the multiple-choice section of the AP Physics 1 & 2 exam about gravitational potential energy. This concept may also be presented in an experimental-type question; the test makers could create a scenario wherein you are conducting an experiment and will give you certain pieces of information and the setup. The exam will then have you determine what other information you need to measure, either directly or indirectly, by asking what instruments are needed to take measurements.

For this type of question, be smart with the information already given. Remember: they want you to choose the method with the least number of measurements made that can fully solve the problem that they have provided in the experiment. Think about how you can cancel out variables using mathematical relationships to minimize the number of measurements. Your answer choice is wrong if you select one that calls for extraneous or superfluous measurements.

The Work-Energy Theorem and the conservation of energy are notorious for being the subject of these experimental questions and often trip students up. For a conceptual, experimental question involving the conservation of energy, you usually don't need more than two other pieces of information. You will recognize this type of question if it involves quantities such as the mass, height, and velocity or spring constant if harmonic oscillators are required.

On the free-response question (FRQ) section of this exam, solving for the gravitational potential energy may be worth one point as the start of a much more complex question. The overall question is going to involve the conservation of energy and the Work-Energy Theorem. This is why we recommend looking at the articles on kinetic energy and the Work-Energy Theorem; along with this article, they will help you better understand what you will be asked on the exam.

# Gravitational Potential Energy Cont.

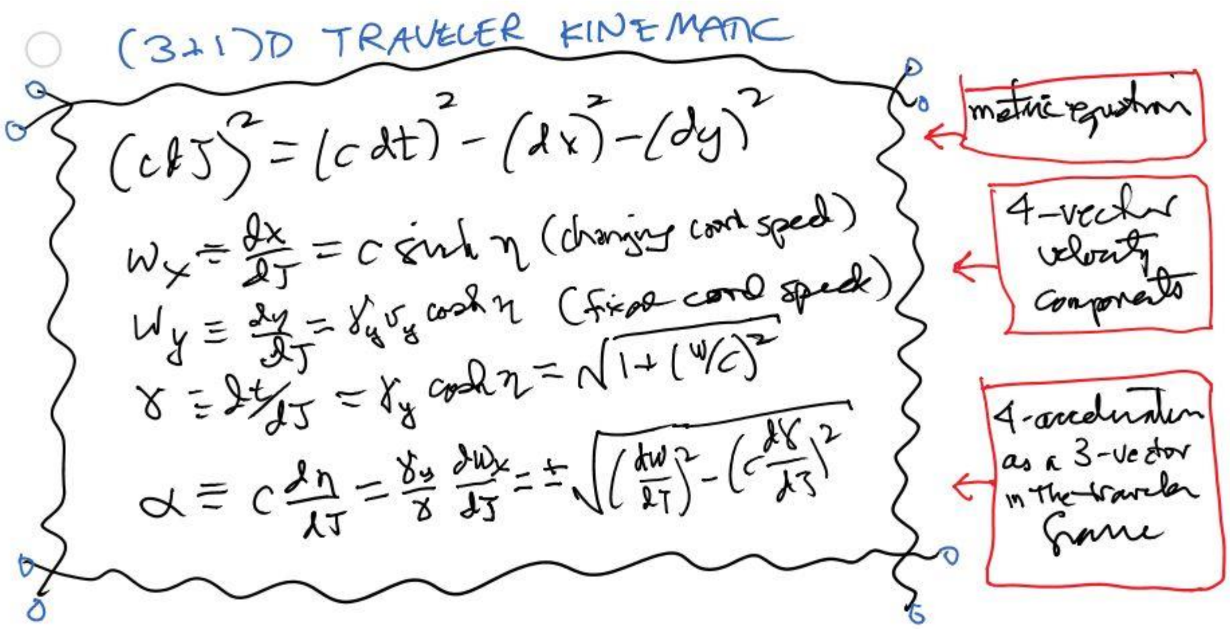
Understanding gravitational potential energy is quite useless on its own. Sure, conceptually it is important. However, it doesn't have any real world applications. Same with spring potential energy or kinetic energy. On their own, they're useless. However, when combined, they can give extremely helpful information about whatever object or systems in question.

If the question asks for any of the components of potential or kinetic energy, such as height, velocity, or mass, remember to equate the two using the Work-Energy Theorem and solve that way. Be sure to choose the correct potential energy, gravitational or spring. However, note that both could be involved if it is a vertically-oriented spring. If this is the case, simply sum the two. The question may be complex and seem confusing, but more than likely it will involve the conservation of energy to some degree.

## Summary of Gravitational Potential Energy

After reviewing this article, you should have a thorough understanding of the most common type of potential energy, gravitational potential energy. We worked through how to derive the formula for GPE, its applications, and, finally, how GPE relates to the AP Physics 1 & 2 Exams. You should feel confident using gravitational potential energy to solve the problems you'll face on the exam. Happy studying!

# Kinematics Review




[Image Source: Wikimedia Commons]

Physics describes the world, and kinematics describes the position of a particle as a function of time. In this AP Physics 1 & 2 Review, we'll review the concepts of position, displacement, velocity, speed, and acceleration in one and two dimensions, and do some practice problems similar to questions on the AP Physics Exams.

# Kinematics Review Cont.

## One-Dimensional Kinematic Quantities

Imagine a bead constrained to move on an infinitely long, horizontal rod. We mark an arbitrary point on the rod and call it the *origin,* O, and label the distance from the origin to the bead with the variable x. x is positive if the bead lies to the right of O and is negative if the bead lies to the left of O.


The goal of one-dimensional kinematics is to describe how the position $x$ varies as a function of time $t$. To do this, we introduce the following quantities:

*Velocity* is how quickly the bead's position varies with time. In the $x$-dimension, we define the velocity $v_x$ such that

$$v_x = (\Delta x) \,/\, (\Delta t).$$

(The delta Δ is read as "change in." $\Delta x$ means "change in $x$.") For example, if the $x$-coordinate decreases by 5$m$ in 10$s$, the velocity is (−5$m$)/(10$s$) = −0.5$m/s$

*Acceleration* is how quickly the velocity varies with time. We define the acceleration $a_x$ such that

$$a_x = (\Delta v_x) \,/\, (\Delta t).$$

# Kinematics Review Cont.

A positive acceleration means that either a positive velocity is increasing in magnitude or a negative velocity is decreasing in magnitude; a negative acceleration means that either a positive velocity is decreasing in magnitude or a negative velocity is increasing in magnitude. For example, if the velocity increases from -10m/s to -5m/s in 2*s*, the acceleration is *positive:*
$-5m/s) - (-10m/s)\} / (2s) = 2.5m/s^2$, even though the particle moves more slowly after the acceleration.

You might have noticed that the velocity tells us in what direction the bead moves, in addition to how quickly it moves. If we want just the latter information, we take the magnitude (or absolute value) of the velocity. This is called *speed:*

$$\text{Speed} = |\text{velocity}| = |v_x|.$$

After some time *t*, we might want to describe how far the particle has moved without reference to its initial or final positions. The difference of these two quantities is indeed the change in the particle's position, called the *displacement:*

$$\text{Displacement} = \Delta x = x_f - x_0.$$

## One-Dimensional Kinematic Equations

Although we won't prove it here, the position *x* as a function of time under constant acceleration is given by

$$x(t) = x_0 + v_{xo}t + \frac{1}{2}at^2,$$

or since $\Delta x(t) = x(t) - x_0$,

$$\Delta x(t) = v_{xo}t + \frac{1}{2}at^2.$$

# Kinematics Review Cont.

In this equation, $x_0$ is the position of the bead at $t$ = 0, $v_{xo}$ is the velocity of the bead at $t$ = 0, and a is the (constant) acceleration of the bead. We can gain insight by taking special cases of this general equation:

For a particle *starting from rest*, $v_{xo}$ = 0:

$$x(t) = x_0 + \frac{1}{2}at^2.$$

For a particle with *constant velocity*, $a$ = 0:

$$x(t) = x_0 + v_{xo}t.$$

Similar to the above equation, the velocity of a particle with constant acceleration obeys

$$v_x(t) = v_{xo} + at.$$

**Uniformly Accelerated Motion**

*A particle starts at x = 4m with initial velocity $v_{xo}$ = 5m/s and constant acceleration a = −5m/s$^2$. At t = 5s, determine the particle's*

*(a) position*

*(b) velocity*

*(c) speed*

*(d) displacement from initial position*

*(e) total distance covered*

# Kinematics Review Cont.

**Solution:**

(a) $x(t) = x_o + v_{xo}t + \frac{1}{2}at^2 = (4m) + (5m/s)(5s) + \frac{1}{2}(-5m/s^2)(5s)2 = -33.5m.$

(b) $v(t) = v_{xo} + at = (5m/s) + (-5m/s^2)(5s) = -20m/s.$

(c) $|v(t)| = |-20m/s| = 20m/s.$

(d) $x(t) - x_0 = -33.5m - 4m = -37.5m.$

(e) This part is tricky: the particle initially has positive velocity which decreases to zero at $t$ = 1$s$ (the particle stops instantaneously), then the particle moves backward until $t$ = 5$s$. We need to find the distance covered in both parts of the motion and add them together.

$$\Delta x(t = 1s) = v_{xo}t + \frac{1}{2}at^2 = (5m/s)(1s) + \frac{1}{2}(-5m/s^2)(1s)^2 = 2.5m.$$

$$\Delta x(t = s) \quad until \quad (t = 5s) = v_{xo}t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(-5m/s^2)(5s - 1s)^2 = -40m.$$

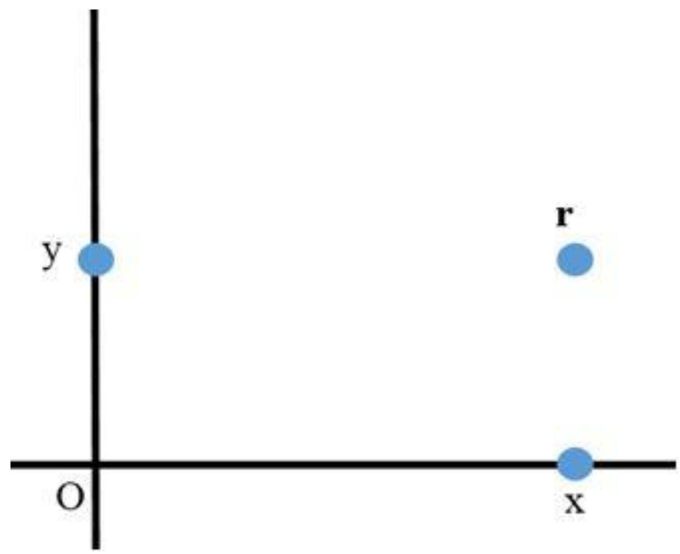
Total distance = $|\Delta x(t = 1s)| + |\Delta x(t = 1s \quad until \quad t = 5s)| = 2.5m + 40m = 42.5m.$

Note that $|\Delta x(t = 1s) + \Delta x(t = 1s \quad until \quad t = 5s)| = 37.5m$, which is just the displacement from part (d).

# Kinematics Review Cont.

**Two-Dimensional Kinematic Quantities**

We now add an extra dimension: the particle can move in the y-direction as well as in the *x*-direction. Imagine that two infinitely long rods meet at right angles in a plane; we put the particle of interest at the same *x* and *y* positions as two beads on the rods:




The *position* of the particle is now a vector (a quantity with a magnitude and direction). If we call the positive $x$-direction $\hat{x}$ and the positive $y$-direction $\hat{y}$, then the particle is at position

$$\vec{r} = x\hat{x} + y\hat{y}.$$

Similarly, the *velocity* of the particle is defined as

$$\vec{v} = \frac{\Delta\vec{r}}{\Delta t} = v_x\hat{x} + v_y\hat{y}.$$

# Kinematics Review Cont.

The *acceleration* satisfies

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = a_x\hat{x} + a_y\hat{y}.$$

The *speed* is the magnitude of the velocity. Since velocity is now a vector quantity, we use the Pythagorean Theorem:

$$v = \sqrt{{v_x}^2 + {v_y}^2}.$$

The *displacement* is the net change in position.

$$\Delta\vec{r} = (\Delta x)\hat{x} + (\Delta y)\hat{y}.$$

Warning: the displacement is only equal to the distance traveled for motion in a straight line, as the following image shows:

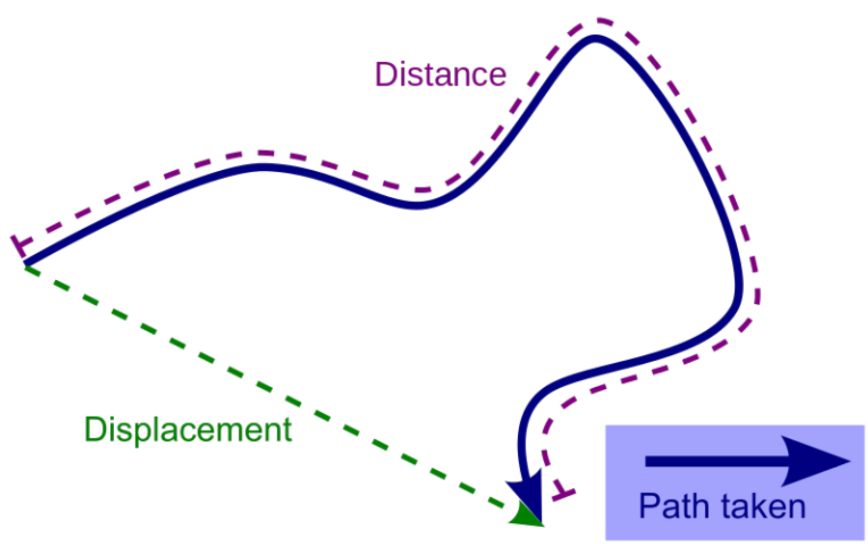


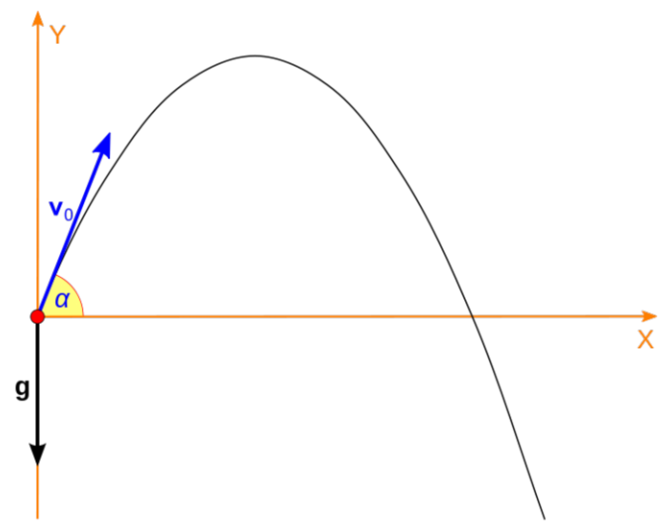

*Image Source: Wikimedia Commons*

# Kinematics Review Cont.

For the case of a round-trip path, the displacement is zero (you end up at your starting position), while the distance traveled can be arbitrarily large!

The following example is vitally important; you should understand every detail.

**Uniform Gravitational Field**




[Image Source: Wikimedia Commons]

*A particle starts at the origin with initial velocity vcosα in the (horizontal) x-direction and vsinα in the (vertical) y-direction. The particle's acceleration is −g in the y-direction. Find*

*(a) The particle's x-coordinate as a function of time*

*(b) The particle's y-coordinate as a function of time*

*(c) The time th when the particle has maximum height*

*(d) The (positive) time tb when the particle has y = 0*

*(e) The x-coordinate xb at the time tb from part (d)*

# Kinematics Review Cont.

**Solution:**

(a) There is no acceleration in the $x$-direction: $x(t) = x_0 + v_{xo}t = v\cos\alpha t$ for all time.

(b) There is both initial speed and acceleration in the $y$-direction:
$y(t) = y_0 + v_{yo}t + \frac{1}{2}at^2 = 0 + v\sin\alpha t + \frac{1}{2}(-g)t^2 = v\sin\alpha t - \frac{1}{2}gt^2.$

(c) The particle reaches maximum height when its y-velocity is zero:
$vy(th) = v_{yo} + ath = v\sin\alpha - gth = 0\ th = v\sin\alpha/g.$

(d) $y(tb) = v\sin\alpha tb - \frac{1}{2}gtb^2 = 0$, giving $tb = 2v\sin\alpha/g.$

(e) $x(th) = v\cos\alpha tb = v\cos\alpha(2v\sin\alpha/g) = v2\sin 2\alpha/g$, from the identity $\sin 2\alpha$

$= 2\sin\alpha\cos\alpha.$

Part (e) gave the *range equation* for a particle launched with speed *v* at angle *α* to the horizontal. This equation tells us how far away the particle will land:

$$R = v^2\sin 2\alpha/g.$$

# Kinematics Review Cont.

## Wrapping Up Kinematics for the AP Physics 1 and 2 Exams

Kinematics is the foundation of physics. Many problems on the AP Physics 1 and 2 Exams use kinematics; the rest of your course consists mostly of introducing different types of forces which produce different types of accelerations (a kinematic quantity).

### One-Dimensional Motion

Definition of velocity:

$$v_x = (\Delta x) / (\Delta t).$$

Definition of acceleration:

$$a_x = (\Delta v_x) / (\Delta t).$$

Definition of speed:

Speed = $|velocity| = |v_x|$.

Definition of displacement:

Displacement = $\Delta x = x_f - x_0$.

Position as a function of time for constant acceleration:

$$x(t) = x_0 + v_{x0}t + \frac{1}{2}at^2$$

# Kinematics Review Cont.

Velocity of a particle with constant acceleration:

$$v_x\left(t\right) = v_{xo} + at.$$

**Two-Dimensional Motion**

Definition of position:

$$\vec{r} = x\hat{x} + y\hat{y}.$$

Definition of velocity:

$$\vec{v} = \frac{\Delta\vec{r}}{\Delta t} = v_x\hat{x} + v_y\hat{y}.$$

Definition of acceleration:

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = a_x\hat{x} + a_y\hat{y}.$$

Definition of speed:

$$v = \sqrt{{v_x}^2 + {v_y}^2}.$$

# Kinematics Review Cont.

Definition of displacement:

$$\Delta\vec{r} = (\Delta x)\hat{x} + (\Delta y)\hat{y}.$$

Range equation:

$$R = v^2 \sin 2\alpha / g.$$

# Distance and Displacement

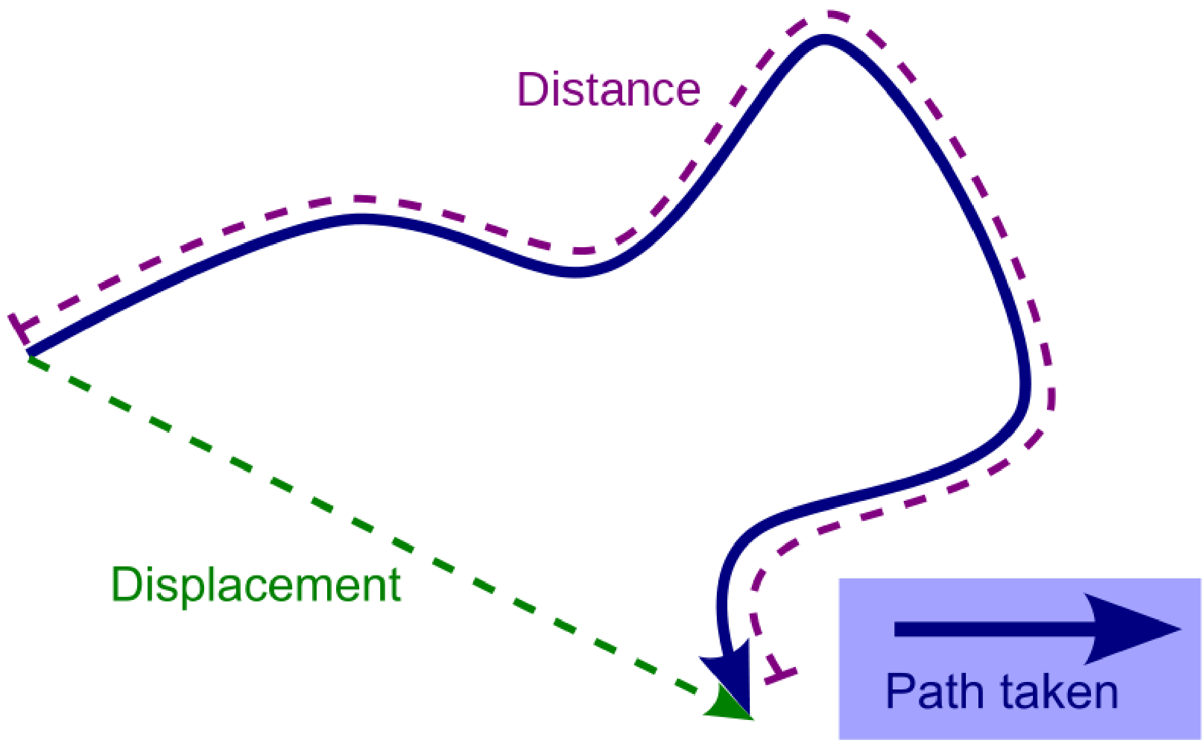



*Image Source: Wikimedia Commons*

While you might find a lot of confusing vocabulary in AP physics, distance and displacement shouldn't be among them. Though both fundamental concepts in kinematics, they are actually quite different from each other. In fact, AP physics loves to test you on the concept of displacement because sometimes it's easy to be mistaken. But don't worry, AP Physics 1 & 2 Crash Course Review will explain what displacement is, how it is different from distance, why we need it and how to calculate distance and displacement in AP physics exam.

# Distance and Displacement Cont.

## What is Displacement?

### 1. Distance vs. Displacement

In short, distance is the length of the path you take while displacement is a change in position. In the figure below, distance is shown in purple and displacement in green. We can see that displacement is always the shortest path.

### 2. Scalar vs. Vector

Another major difference between distance and displacement is that distance is a scalar and displacement is a vector. Forgot what is a scalar or vector? Scalar is a quantity that involves only magnitude. We can simply interpret it as a number. Examples of scalars are mass, length, temperature etc. Vector is a quantity that involves both magnitude and direction, so vector is incomplete without a description of direction. Examples of vectors are distance, velocity, acceleration, force, etc. Typically a vector is denoted in several ways: **A** , ***A*** or $\vec{A}$.

**About Notation**
We use "Δ" (delta) to represent "change" in physics, for example, change in height (Δh), change in length (Δl), change in temperature (ΔT) and so on. Without special notice, we usually use Δx for horizontal change in position, Δy for vertical change in position and Δs for general displacement.

Example 1

*A and B are 2 points on the x-y coordinate plain. Object P moves directly from A to B. At the same time, another object Q moves from B to A. Does displacement ΔSp equal to ΔSq?*

Though their displacement's magnitudes, distance, are the same. the vectors ΔSp and ΔSq have different directions. One points from A to B, and the other points from B to A. So ΔSp doesn't equal to ΔSq.

# Distance and Displacement Cont.

To sum up, displacement is different from distance in two ways:

1. Displacement is only about the change of position and is independent of travel path. Distance is the length of travel path.

2. Displacement is a vector with magnitude and direction. Distance is a scalar with only magnitude.

## Why do We Define Displacement?

You may wonder why we need displacement. Isn't distance good enough to depict a movement? Actually, there are many variables that are independent from distance. For example, distance is irrelevant when we calculate gravitational potential energy. It doesn't matter which path the object takes. We can figure out gravitational potential energy as long as the initial and final position is fixed. Also, it makes calculations much easier sometimes if we use displacement instead of distance. In simple harmonic motion, for instance, the force given by the spring is related to the displacement from equilibrium. Even if the object travels back and forth, the force on it remains the same every time it reaches the same position.

But we do need distance sometimes. Let's say you are trying to slide your new sofa into the correct position. The amount of work required is related to the length of the path that you take, since work equals to friction times distance. If you have to slide the sofa in a zigzag path because the desk is blocking the way, you will have to do more work than pushing it in a straight path. Similarly, the longer the distance is, the more work is required to overcome friction.

Now you probably have already remembered distance and displacement. If you' re not, just keep in mind that displacement is related to "place" and position.

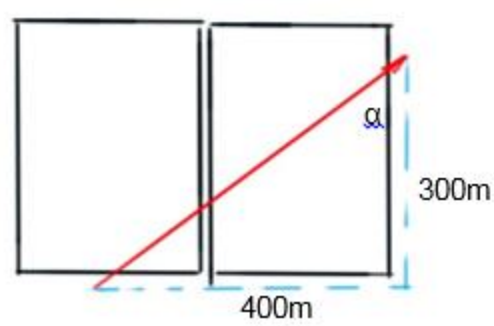
# Distance and Displacement Cont.

## How to Compute Distance and Displacement?

Example 2:

*Suppose you need some paper cups so you decide to go to a grocery store which is 2 blocks away from your home. You first walk 400m to the east, then 300m to the north. What is you're the total distance and displacement for your trip to the grocery store?*

To solve problems of distance and displacement in AP physics, the first step you should take is to make a sketch because it is the easiest and most direct way to understand what is said in the problem. By drawing a sketch, you could convert a physics problem into a geometric problem.




Calculating displacement is a little bit more complicated than that. Still, in the same example, displacement Δs is merely the net change in position. We could see that the horizontal position changes 300m, vertical position changes 400m. Then apply Pythagorean theorem to calculate $\Delta s = \sqrt[2]{(\Delta x)^2 + (\Delta y)^2}$ $= \sqrt[2]{400m^2 + 300m^2} = 500m$. So the displacement is *500m*? You are ALMOST there. You should also add the description of direction. In this triangle, sinα = 400m/500m = 4/5. So α = arcsin(4/5) and the CORRECT answer to this question is *500m to arcsin(4/5) degree north of east*.

# Distance and Displacement Cont.

Now you have a sense of how to calculate displacement, here are usual steps to calculate it:

1. Draw a sketch.

2. Find out horizontal and vertical net distance.

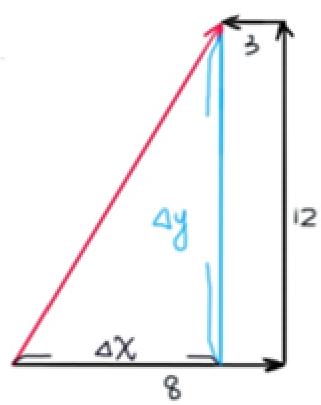
Use Pythagorean theorem to calculate $\Delta s = \sqrt[2]{(\Delta x)^2 + (\Delta y)^2}$

Ready to move on? Let's try another example.

Example 3

*A worm crawls 8cm to the east, 12cm to the north and 3cm to the west. What is the total distance and displacement?*

First, let' s draw a sketch as follow. The total change in position is showed as the red arrow. 8cm to the east and 3cm to the west actually makes a net distance Δx of 5cm in the horizontal direction. 12cm to the north makes a net distance Δ y of 12 cm in the vertical direction. So the total displacement $\Delta s = \sqrt[2]{(\Delta x)^2 + (\Delta y)^2} = \sqrt[2]{(8cm - 5cm)^2 + 12cm^2}$ = 13cm.



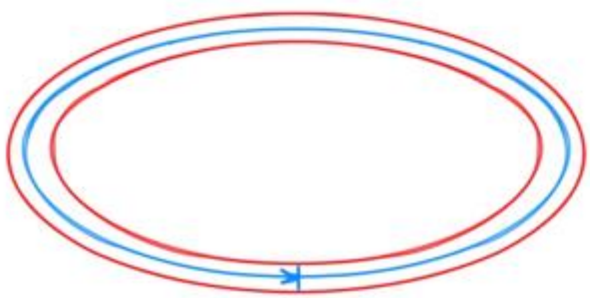

Again, don't forget to add the direction to arcsin(12/13) degree north of east.

# Distance and Displacement Cont.

Example 4:

During a sports meeting, an athlete runs exactly once around a 400m oval track. Find the distance and displacement for the race.

Since the athlete runs exactly 400m, the distance of the race is 400m. What about displacement? He returns to the same position where he starts, so the net distance is 0. Don't ever hesitate to write down zero if you encounter this kind of questions in a real test. Remember, displacement is only about position.



## Mastering Displacement-related Questions

Distance and displacement are some of the most basic concepts in AP physics 1&2 test so it's very unlikely that you will encounter questions asking solely about them in a real test. In fact, they are always combined with other kinematics concepts such as velocity and acceleration. But the calculation of distance and displacement is still a fundamental skill while learning kinematics.

In this article, we discuss what distance and displacement are, why we define them and how to solve related question in AP physics 1&2 tests. It is a very nice start for kinematics if you are already very familiar with them. If you are still not that clear, just remember 3 vital things that will probably help you on the test day:

1. Displacement is a change of position.
2. Displacement is a vector with direction.
3. Use Pythagorean theorem to calculate Displacement.

# Torque

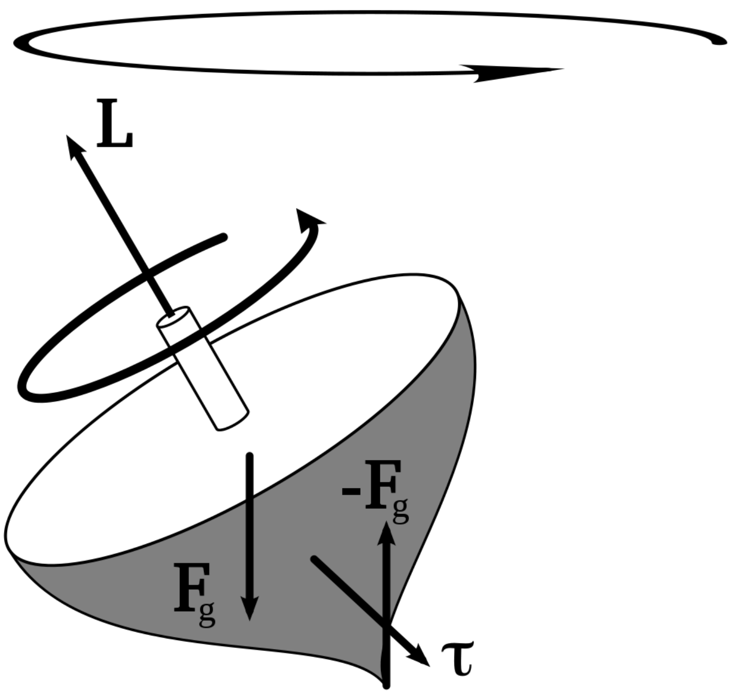



Image Source: Wikimedia Commons

If you're reading about torque, you've probably already covered work, which measures a force applied that displaces an object in any direction on a Cartesian coordinate system (x/y coordinates). Now, what if we take that same object and rotate it around a fixed axis? When we do that, we are applying a torque on that object.

Let's clarify the difference with examples. If there is a box and I am pushing it horizontally, I am doing work on it. If I push it onto an inclined plane to load it onto the back of a truck, it's still work because the box is not fixed on any particular axis. However, if I take that box and put it on one end of a seesaw, with myself standing at the other, both the box and I are applying torques on the seesaw. The seesaw's fulcrum fixes it on an axis that causes rotational motion.

# Torque Cont.

## Understanding Torque

Like work, torque is a force multiplied by a distance. However, the difference lies in how force and distance are multiplied, and what kind of distance is used in this scenario. For work, the force (*F*) and the distance (*d*) were multiplied by a dot product. Because it is the dot product of two vectors, it is a scalar value.

$$W = F \cdot d = Fd\cos\theta$$

Torques, however, involve rotation along a fixed axis. Therefore, instead of a dot product, we need to use a cross product. We also can't use the distance d that we applied in the previous work equation because we are not displacing the object a certain distance. We are rotating it along a fixed axis. To calculate torque we must introduce a new vector, r. Physically, it is the distance from the axis of rotation to the point where the force is applied.

$$\tau = r \times F = rF\sin\theta$$

Torque is the cross product of two vectors, which means that torque is also a vector. This can make torque problems quite tricky and difficult to understand. We'll go over an example later on in this article to show you how you can go ahead and solve one of these.

First, let's look at the physical meaning of this equation for one second. Because of the cross product, we end up with an equation with a sine term, rather than the dot product for work, which netted us a cosine term.

That means that if the force occurs perpendicular to the direction of motion, the work done would be zero because that would mean our cosine term would be cos (90°) = 0. For torque, on the other hand, because of the sine term, there would be no torque if the force were applied parallel or anti parallel to the direction of motion, because sin (0°) = sin (180°) = 0.

# Torque Cont.

Therefore, torque only occurs if the force applied to the object has a component that is perpendicular to the r vector. This means that, although it is a force multiplied by a distance, its units aren't in joules (J) like work or energy. Instead, the units are just newton-meters (N•m). In this case, newton-meters and joules are not interchangeable due to their implications.

It should also be noted that torque can be calculated on different points on an object. The r vector in the torque equation can technically start at any point so long as it ends at the point on the object where the force is applied. As we will see in our free response example from an AP Physics test, skillfully choosing the starting point for r can simplify torque problems.

## Other Implications of Torque

As a result of torque's rotational nature, there are certain terms that go along with it that have Cartesian analogs. This is necessary because we're now operating on a different axis and plane.

First up, we have distance. The rotational equivalent would be the angular displacement (θ – lower-case Greek letter theta), and it is in radians (rad). Next is angular velocity (ω – lower-case Greek letter omega). In Cartesian velocity, we had units of m/s.

Because the axis is rotational for angular velocity, the units are in circular terms. In SI The SI unites would be radians per second (rad/s). Going off of that, we have angular acceleration (α – lower-case Greek letter alpha) in units of radians per second squared ($rad/s^2$). It also causes angular momentum, but that's a more complex topic covered in a different topic.

To reiterate, torque is a vector. So we can calculate the magnitude, but what is the direction? For the purpose of the AP Physics 1 & 2 exam, you only need to know clockwise or counterclockwise. Now is the cue for you to turn to your nearest clock and figure out which direction is which way. Don't pretend like you didn't need to do that. It's ok, though, only your computer is judging you.

# Torque Cont.

Depending on which is more convenient for you and makes more sense for that particular problem, you can assign either direction as positive or negative. Traditionally, however, a positive direction is indicative of counterclockwise direction, while you assign clockwise motion with a negative direction. Again, it's up to you to choose depending on which is more convenient for you.

### Torque-Based Free-Body Diagrams

So you thought you never had to worry about free-body diagrams again after learning about forces, now did you? Well, sorry to inform you, but from that point on, free-body diagrams will govern everything you do. They are incredibly useful in determining physical quantities and properties. If you're still shaky on those, please review them before proceeding. You will continue to struggle throughout this course if you cannot fully master free-body diagrams.

There is a torque analog of a free-body diagram. When you were using free-body diagrams to determine forces, you represented the object as a single point. For torques, however, you use a straight line to represent the object. This is because the object rotates about a fixed axis, such as a fulcrum. The distance from the axis of rotation is what determines torque, so on the diagram, you need also to indicate *r*, which is known as the torque arm. Below is an example.

*Image Source: Physics Lab*

# Torque Cont.

The different arrows represent the forces that are being applied to the torque arm with the respective directions in which they are being applied. Notice that the length of the torque arm is also included, *L*. 0.5 *L* obviously represents half of the full length of the arm.

Similar to [forces](), if there's no movement and it's at equilibrium, there is no net torque. You can use this information to set up an equation that allows you to calculate certain pieces of information.

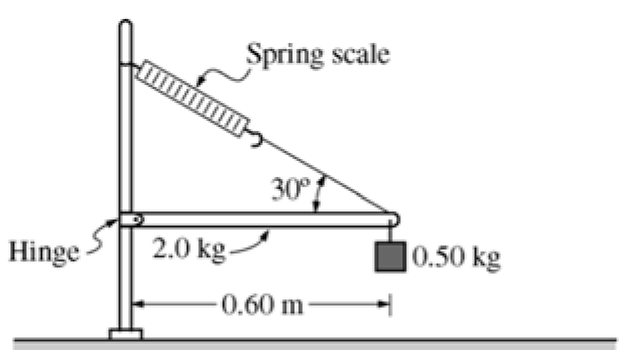
### Torque and AP Physics 1 & 2 Exam

Torque is such an integral part of physics. You can expect several conceptual questions on the multiple choice related to torque. Regarding the free-response question (FRQ), you should prepare for a full question related to rotational motion that incorporates almost all of everything that you've learned in the course so far.

Torque is only a small part of rotational motion, so when you get more into rotational motion topics such as angular momentum and rotational inertia, you'll get a better idea and understanding of what these problems will look like.

We will work on an example from the AP Physics C Mechanics exam from 2008. Although it is from the AP Physics C exam, we will only cover the first two parts of the question, which are fair game for the AP Physics 1 & 2 exam.

This is question 2 from the AP Physics C mechanics exam from 2008.



# Torque Cont.

*The horizontal uniform rod shown above has length 0.60 m and mass 2.0 kg. The left end of the rod is attached to a vertical support by a friction-less hinge that allows the rod to swing up or down. The right end of the rod is supported by a cord that makes an angle of 30° with the rod. A spring scale of negligible mass measures the tension in the cord. A 0.50 kg block is also attached to the right end of the rod.*

*(a) On the diagram below, draw and label vectors to represent all the forces acting on the rod. Show each force vector originating at its point of application.*

*(b) Calculate the reading on the spring scale.*

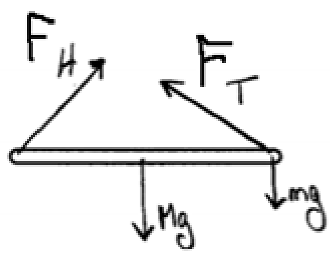
Well, that looks like quite a contraption. However, it's important not to get too caught up in the appearance of a problem that you forget how to solve it methodically. It's quite simple. CollegeBoard already gave us the first step in solving this problem. Let's draw the forces on the lever.

Let's start at the left. We are told that the rod is attached to a hinge. The hinge provides support up and to the right, so we'll draw the arrow in that direction. We aren't given an angle on the hinge, but we'll figure out later it's unimportant. It is important to draw these arrows such that they originate at the lever arm. Next, we have the cord, which is pointed up and to the left from the rod at 30$^{o}$.

Next, we need to take into account the mass of the block, which we'll denote as *m*. We will have that pointing downward from the right end of the rod. Finally, we take into consideration the mass of the rod itself, denoted by large *M*.

# Torque Cont.

As mentioned above, it's a uniform rod, so we can assume its center of mass is at its actual physical center. Here is what the diagram should look like.




So, part (a) is taken care of. Let's move onto part (b). Let's first ask ourselves what the reading on the spring scale represents. It is attached to the cord that is attached to the rod. The cord is represented by the tension force, $F_T$, as indicated by the diagram. So we are essentially solving for $F_T$.

Now let's remember that the rod is at rest. Therefore, the sum of all torques is zero.

$$\sum \tau = 0$$

Remember how we said we don't need to know anything about $F_H$? Here's why: we can set the hinge as the starting point for our r vector. Therefore, r and r Fsin (θ) zero point on the arm. It's quite convenient as well, seeing that it is actually at the far left of the rod.

Let's set up the expression for the torques acting on the y-axis. The length of the rod is denoted by *L*.

$$\sum \tau_y = -\frac{L}{2}Mgsin(90^o) + F_\tau Lsin(30^o) - Lmgsin(90^o) = 0$$

# Torque Cont.

Let's do some algebra to eliminate negatives. We can also cancel every sin(90°) by recognizing that sin(90°) = 1.

$$F_T L sin(30^o) = \frac{L}{2}Mg + Lmg$$

Next, we can eliminate the length of the rod as it is present in each term in the expression. That allows us to solve for $F_T$.

$$F_T = \frac{g(0.5M+m)}{sin(30^o)}$$

Plug in the numbers and get our final answer for part (b), the reading on the spring scale.

$$F_T = \frac{(9.8m/s^2)(0.5(2.0kg)+0.50kg)}{sin(30^o)} = 29N$$

On the AP exam, this is only going to be a part of a problem of a full FRQ on rotational motion that is covered in other articles regarding angular kinematics such as angular momentum. Setting up the diagram is important, however, as that will dictate how well the rest of the problem goes. On the multiple choice part, you will find conceptual questions related to torque. Make sure you understand the concept of it fully.

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# Fluids Review

*Image Source: Pixabay*

Fluids are any matter that can flow – gases and liquids are both fluids, and we use the same physical equations to describe their characteristics. In this AP Physics 1 and 2 review, we'll review fluid statics, fluid dynamics, and do some practice problems similar to those you would see on the AP Physics 2 exam.

# Fluids Review Cont.

## Fluid Statics vs. Fluid Dynamics

Fluid statics and fluid dynamics are the studies of stationary and moving fluids, respectively. The molecules of a fluid at rest, such as the gasoline molecules in a car tank, are very much in motion, but this fluid is not dynamic because the net motion of all molecules is zero. Likewise, any motion of the car would cause fluid movement relative to the ground, but still no movement relative to the car tank. We can summarize these observations: fluid dynamics applies when the fluid is in *motion relative to its container*.

In both fluid statics and dynamics, we use these variables to describe the fluid matter:

1. Pressure, measured in Pascals (*Pa*) and denoted by the capital letter *P*

   *Pressure=Force/Area*.

2. Density, measured in $kg/m^3$ and denoted by the Greek letter $\rho$ (rho).

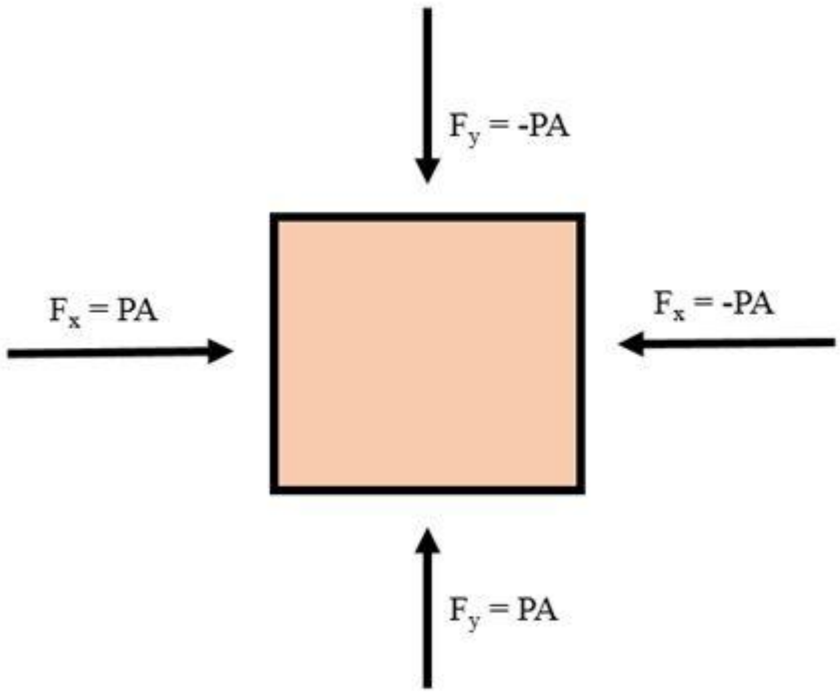
   *Density=Mass/Volume*.

## Statics: Hydrostatic Pressure

Consider the following thought experiment: take a very small cube of wood and submerge it in fluid of equal density. The fluid shows no net movement, and neither does the wood: it is in equilibrium, and $\vec{F_{net}} = 0$.

# Fluids Review Cont.

If the cube is vanishingly small, we can assume its mass and the gravitational force acting on it are both zero. Thus, the oppositely-directed forces from fluid pressure must cancel for every pair of opposite cube faces:

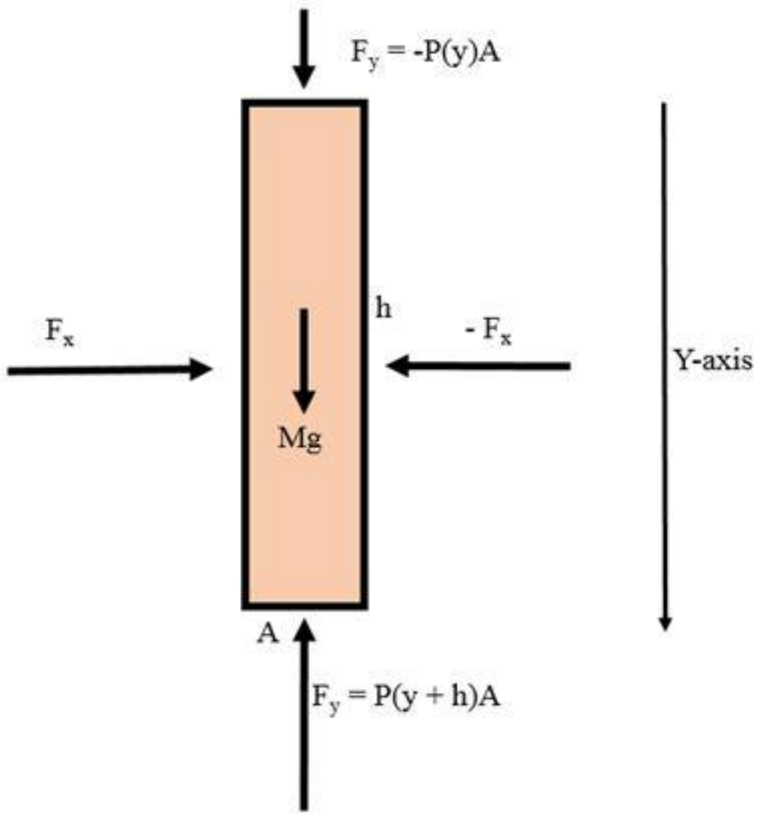



This tells us that the pressure on each face of the cube (in any one of the six directions) is the same. More generally,

Each point in a volume of stationary fluid has a pressure associated with it which is independent of direction.

# Fluids Review Cont.

Now, assume the cube is not vanishingly small. We change it to a rectangular prism with base area *A* and height *h*, and the gravitational force is no longer negligible.




The rectangular prism is still in equilibrium, so $F_{net}$= 0. There is no gravitational force in the *x*-direction, so the pressure forces in the *x*-direction are still equal. However, there is now a gravitational force in the *y*-direction, so the pressure on the bottom of the prism must be greater to compensate. Let the *y*-axis point down, and let the top and bottom prism faces be at coordinates *y* and *y*+*h*, respectively.

$$F_{net,y} = -P(y)A - Mg + P(y+h)A = 0$$

# Fluids Review Cont.

By the definition of density,

$$M = \text{(density) (volume)} = \rho(Ah)$$

Substituting this into the force equation, we obtain the *hydrostatic pressure equation:*

$$P(y+h) - P(y) = \rho g h$$

This means that pressure increases as you move deeper into a fluid and does not change as you move horizontally (the equation has no *x*-dependence). For example, the pressure at the bottom of the ocean is greater than the pressure at the top because water at the ocean floor must support the weight of all the water above it.

**Deep Sea Diving**

*The density of water is 1000kg/m$^3$, and the Mariana Trench is at most 11km below sea level. If the air pressure at sea level is 101kPa, what is the hydrostatic pressure at the bottom of the Mariana Trench? Assume the density of water is uniform.*

**Solution:**

The water on the surface of the sea is at atmospheric pressure. Let sea level be *y*=0; the hydrostatic pressure equation yields

$$P(11000m) - P(0) = (1000kg/m^3)(9.8m/s^2)(11000m) = 107.8MPa$$

$$P(11000m) = 107.8MPa + 101kPa = 107.9Mpa$$

# Fluids Review Cont.

At the deepest ocean bottom, the atmospheric pressure is about a thousand times smaller than the additional pressure due to the weight of water.

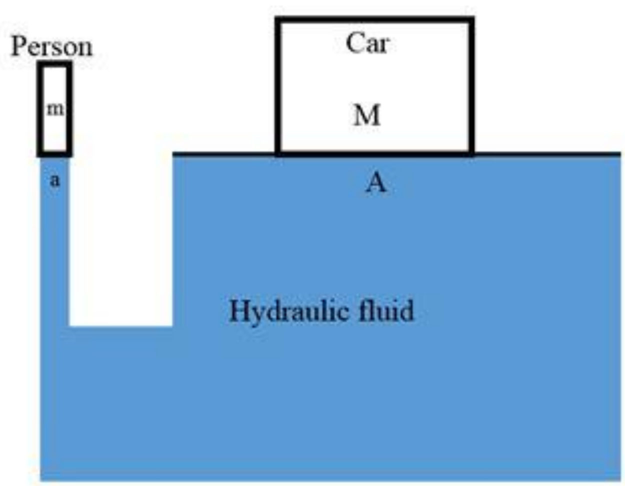
## Statics: Pascal's Principle

Consider again the hydrostatic pressure equation, $P(y + h) - P(y) = \rho gh$. If we increase $P(y)$ by the amount $\Delta P$, then $P(y + h)$ must also increase by $\Delta P$ in order to keep the right side of the equation equal to $\rho gh$. This is a general result due to the Frenchman Blaise Pascal and is called *Pascal's Principle.* An additional pressure exerted anywhere in an incompressible fluid is transmitted to all other points in the fluid. Not only does $P(y + h)$ increase by $\Delta P$, but $P(y + 4m)$, $P(y + 5h)$, and $P(y - 6m)$ increase by $\Delta P$ as well. Pascal's principle holds only for *incompressible* fluids, which have constant volume regardless of pressure. This principle is the basis for a field of engineering called *hydraulics.*

### Car Jack

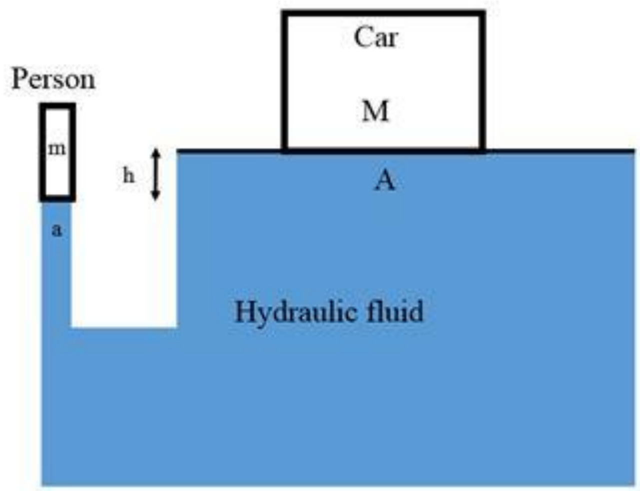
*A car jack consists of a small vertical tube of area $a = 0.1m^2$ connected to a large vertical tube of area $A = 10m^2$, both of which are filled with water of density $1000kg/m^3$. A car of mass $M = 1000kg$ sits on a metal plate on top of the large vertical tube; you stand on a metal plate on the small vertical tube. How heavy must you be to balance it by standing*

*(a) At the same height as the car?*



# Fluids Review Cont.

*(b) A distance h = 0.5m below the car?*




**Solution:**

Since pressure is force over area, the pressures exerted by you and the car are

$$P_{person} = mg/a$$

$$P_{car} = Mg/A$$

(a) Since the fluid heights just below you and the car are equal, the pressure on both sides is equal:

$$P_{person} = P_{car}$$

$$mg/a = Mg/A$$

$$m = Ma/A = (1000kg)(0.1m^2)/(10m^2) = 10kg$$

# Fluids Review Cont.

(b) You and the car are no longer at the same height; by the hydrostatic pressure equation, the pressure directly underneath you is greater.

$$P_{person} - P_{car} = \rho g h = (1000kg/m^3)g(0.5m) = (500kg/m^2)g$$

$$mg/a - Mg/A = (500kg/m^2)g$$

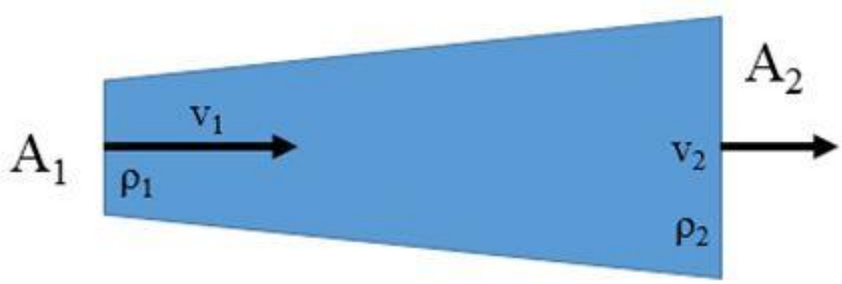
$$m = [(500kg/m^2) + (1000kg)/(10m^2)](0.1m^2)$$

$$= 60kg$$

You must be 50*kg* heavier to sink to 50*cm* below the height of the car. Your additional weight is supported by the fluid below the car's metal plate but above your metal plate.

## Dynamics: Equation of Continuity

Imagine a fluid flowing through a pipe of changing cross-sectional area. The positive *x*-direction points horizontally to the right, and the fluid density *ρ*, flow speed *v*, and cross-sectional areas *A* at each end of the pipe are labeled below.



# Fluids Review Cont.

By conservation of mass, the mass that enters the pipe per unit time must equal the mass that exits per unit time. By the definition of density, mass = (density)(volume). Dividing by a time interval $\Delta t$ and using the volume equation $\Delta V = A\Delta x$,

$$\frac{\Delta m}{\Delta t} = \rho \frac{\Delta V}{\Delta t} = \rho A \frac{\Delta x}{\Delta t} = \rho A v.$$

This is the mass flow per time and must be the same everywhere in the tube. It is called the *equation of continuity* and is the statement of mass conservation for a flowing fluid:

$$\rho A v = constant$$

To use this equation, simply apply it at two different x-coordinates, 1 and 2:

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

Generally, the fluids you meet in AP Physics 2 are incompressible, which means their density is constant, $\rho_1 = \rho_2$ for any $x$-coordinates 1 and 2. Therefore, the equation of continuity for an *incompressible* fluid can be simplified to

$$Av = constant$$

$$A_1 v_1 = A_2 v_2$$

# Fluids Review Cont.

**River Mouth**

*A river of constant depth increases from 10 m in width at its source to 100 m in width at its mouth. Assuming that the water it carries is incompressible, what is the ratio of current speed at its mouth to current speed at its source?*

*(a) 10*

*(b) 1/10*

*(c) 100*

*(d) 1/100*

**Solution:**

The cross-sectional area of the fluid is given by Area = (depth) (width). Since the depth is constant, the cross-sectional area at the river mouth is 10 times greater than at its source.

By the continuity equation for an incompressible fluid,

$$A_{mouth}v_{mouth} = A_{source}v_{source}$$

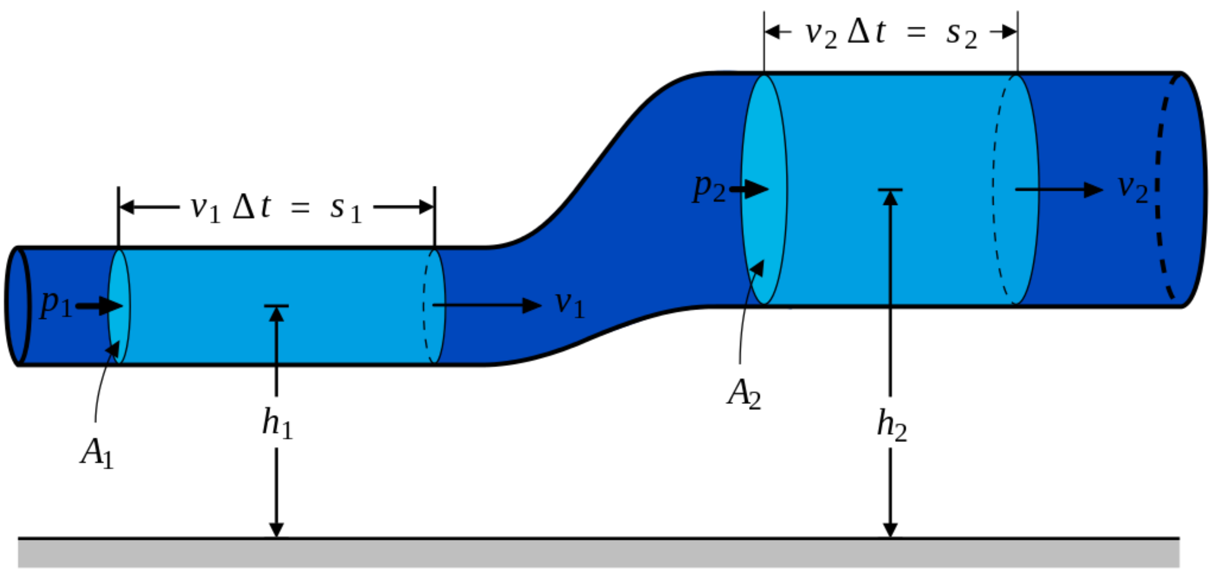
$$v_{mouth}/v_{source} = A_{source}/A_{mouth} = 1/10$$

The answer is (b). The continuity equation explains why narrow rivers tend to flow faster than very wide ones.

# Fluids Review Cont.

**Dynamics: Bernoulli's Equation**

Just as the continuity equation is a statement of mass conservation, Bernoulli's equation is a statement of energy conservation. The derivation is given below, but it's tricky; you may skip it if you want and go straight to the equation itself.




[Image Source: Wikimedia Commons]

Imagine that a volume of the fluid is initially between the cross sections $A_1$ and $A_2$ and moves for a time $\Delta t$. This movement produces an "effective transfer" of part of the fluid of mass $m$ (shown in light blue) from the lower height $h_1$ to the top height $h_2$.

Since work is force times distance, the work done by the pressures at the lower height and top heights are

$$W_{p1} = P_1 A_1 s_1, W_{p2} = P_2 A_2 s_2$$

# Fluids Review Cont.

The gravitational work done is

$$W_g = -mg(h_2 - h_1)$$

Since work is change in kinetic energy,

$$K_1 + W_{p1} + W_{p2} + W_g = K_2$$

$$\tfrac{1}{2}mv_1 + P_1A_1s_1 + (-P_2A_2s_2) + (-mg(h_2 - h_1))\tfrac{1}{2}mv_2$$

Note that the volume of the fluid element of mass m is constant:

$$V = A_1s_1 = A_2s_2$$

Since density = mass / volume, we divide the entire energy equation by *V* to obtain

$$\tfrac{1}{2}\rho v_{12} + P_1 - P_2\rho g(h_2 - h_1) = \tfrac{1}{2}\rho v_{22}$$

$$\tfrac{1}{2}\rho v_{12} + \rho g h_1 + P_1 = \tfrac{1}{2}\rho v_{22} + \rho g h_2 + P_2$$

We have derived *Bernoulli's Principle*, which says that the quantity

$$\tfrac{1}{2}\rho v^2 + \rho g h + P = constant$$

is the same everywhere in a flowing, incompressible fluid.

# Fluids Review Cont.

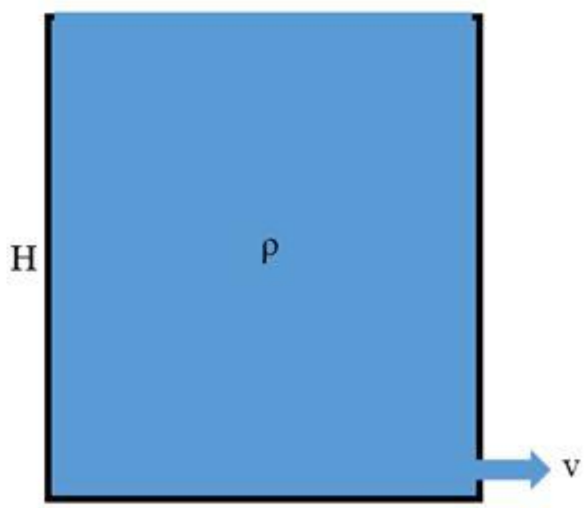
You may have noticed that Bernoulli's Principle gives a quantity similar to the total energy of a mass m in a uniform gravitational field,

$$E = \frac{1}{2}mv^2 + mgh = constant$$

The extra term in Bernoulli's Principle accounts for the work done by the pressure. For example, a fluid flowing upwards must feel a pressure that produces an effect greater than that of gravity.

**Torricelli's Theorem**

A very large, open container of height *H* filled with fluid of density ρ springs a leak at its bottom. What is the speed of the fluid that flows out of the container?




**Solution:**

Since the container is very large, the speed of the fluid level's drop at the top of the container is negligible. Both the top of the container and the leak are open to the atmosphere, so both are at atmospheric pressure, $P_{atm}$.

# Fluids Review Cont.

By Bernoulli's Principle applied at the top and leak of the container,

$$\frac{1}{2}\rho v_{12} + \rho g h_1 + P_1 = \frac{1}{2}\rho v_{22} + \rho g h_2 + P_2$$

$$0 + \rho g H + P_{atm} = \frac{1}{2}\rho v_2 + 0 + P_{atm}$$

$$v = \sqrt{2gH}$$

The speed of the fluid outflow equals the speed of a ball dropped from height *H*. Both speeds ultimately are derived from energy conservation.

### Wrapping up Fluids for the AP Physics 2 Exam

Pressure is measured in Pascals (*Pa*) and denoted by the capital letter *P*.

$$Pressure = Force/Area.$$

Density is measured in $kg/m^3$ and denoted by the Greek letter $\rho$ (rho).

$$Density = Mass/Volume.$$

Hydrostatic pressure equation:

$$P(y + h) - P(y) = \rho g h.$$

# Fluids Review Cont.

Pascal's Principle:

An additional pressure exerted anywhere in an incompressible fluid is transmitted to all other points in the fluid.

Equation of continuity:

$$\rho A v = constant.$$

Bernoulli's Principle

$$\frac{1}{2}\rho v^2 + \rho g h + P = constant.$$

# Circuits Review

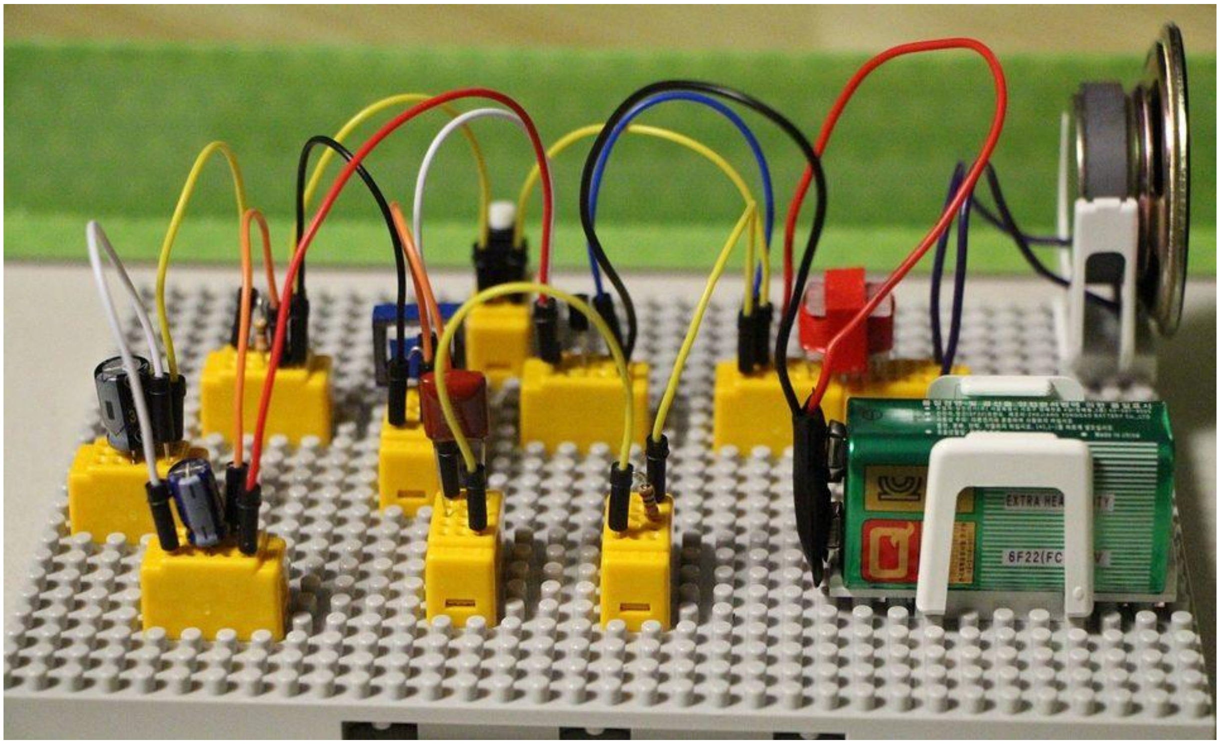


*Image Source: Pixabay*

Put simply, a circuit is a closed conducting wire loop with some elements in the mix, such as batteries, resistors, and capacitors. Only batteries and resistors are covered in AP Physics 1; Physics 2 also covers capacitors. In this article, we'll review the characteristics of circuits, resistors, and capacitors and do some example problems similar to those on the AP Physics 1 and 2 exams.

# Circuits Review Cont.

## Current

Electric current is defined as the charge passing through a cross-sectional area per time:

*Electrical current = charge per time.*

Charge is measured in Coulombs ($C$), so current has units of Coulombs per second, or Amperes: $1A = 1C/s$. For example, if 5.0C$5.0C$ of charge passed through a resistor in $10s$, the current would be $(5.0C)/(10s) = 0.5A$. Physicists usually denote current by the letter $I$. Both lowercase and capital letters are commonly used.

Here's a brief explanation of the microscopic origin of electrical current:

**Electrical Current: a Brief Microscopic View**

Electrical circuits are useful because they manipulate the flow of electrical charge. Imagine a metal wire. You might know from chemistry class that metallic bonds are formed when every atom shares its valence electron(s) with all other atoms – the electrons are not "attached" to any individual atom, and hence form an "electron sea."

When the electron "sea" exhibits net movement in a particular direction along the wire, we say that the wire carries an *electrical current*. The electrical current moves in the opposite direction from the electrons because electrons are negatively charged; physicists use the direction positive charges *would* move (if they could move, as atomic nuclei are heavy) as a sign convention.

The electron "sea" moves very, very slowly (on the order of micrometers per second), but there are so many electrons that even very slow motion produces a measurable current.

Although the actual electrons may not travel all the way around the circuit, the current must do so. This is why circuits must be *closed,* or have no gaps. If the circuit has a gap, then there is no path for the current to make a round-trip, and we say the circuit is *open.*

# Circuits Review Cont.

In a steady-state circuit, there is no charge build-up in any node (a node is where two or more wires come together.) Therefore, the current coming into the node must equal the current leaving the node:

*Current in = current out.*

This is called *Kirchhoff's node rule, Kirchhoff's junction rule,* or *Kirchhoff's first law*. It is a statement of the principle of charge conservation at a circuit node.

### Voltage

Voltage difference is defined as the change in potential energy per unit charge:

*Voltage difference = (change in potential energy) / (charge).*

Since potential energy is measured in Joules ($J$) and charge in Coulombs ($C$), voltage is measured in Joules per Coulomb, or Volts: $1V = 1J/C$. Physicists denote voltage by the capital letter $V$. We say voltage "difference" because no point in a circuit has a specific, true voltage – only the difference in voltage between two points in a circuit has physical meaning.

When current passes through a circuit element, the charged particles may gain potential energy (positive voltage difference) or lose potential energy (negative voltage difference). There is a particular voltage difference across each circuit element, but when the current makes a round-trip, its energy must be the same as when it started:

*The sum of voltage differences in a closed loop must be zero.*

This is called *Kirchhoff's loop rule* or *Kirchhoff's second law*.

Keep in mind that the terms "voltage difference," "potential difference," "voltage drop," "change in potential," and other similar terms all mean the same thing.

# Circuits Review Cont.

Typically, batteries are required to keep the electric current in a circuit nonzero. More specifically, the resistance of a circuit causes energy loss, which is replenished by the chemical energy of a battery. The voltage across a battery is called the *electromotive force,* or *emf:*

*Emf = electromotive force = voltage increase across a battery.*

The electromotive “force” is not a true force; the name is a historical relic that nobody’s bothered to replace yet. You can read the emf of a battery on its label; for example, the small rectangular batteries usually have an emf of 9*V*.

The circuit symbol for battery on the AP exams is:

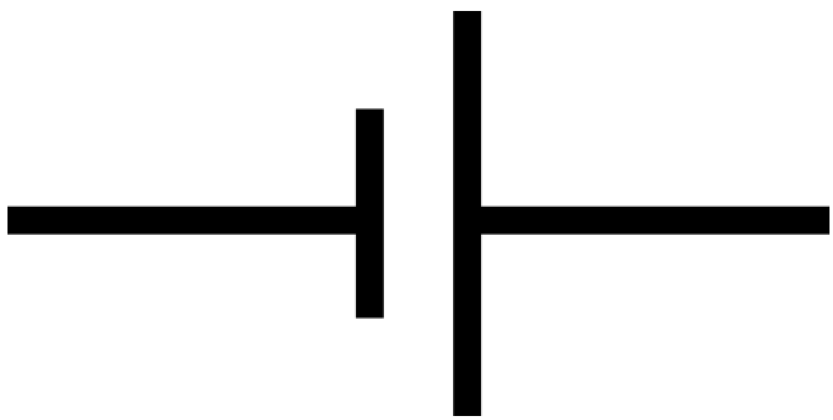


*Image Source: Wikimedia Commons*

The longer line on the battery symbol always represents the higher voltage. (You may see batteries with more lines; there should still be one short and one long line at the ends of the symbol.) If the emf of the battery is 9*V*, then we say the potential difference across the battery from left to right is 9*V*. The potential difference from right to left is −9*V*.

# Circuits Review Cont.

## Resistance

Resistance is a quality of a circuit element that causes energy loss. For example, if the material of a wire is not perfectly conducting (nothing is, save superconductors), then energy will be lost when current flows through the wire. Often, circuit elements are designed that purposely cause the loss of energy; these circuit elements are called *resistors*. The circuit symbol for a resistor on the AP exam is:

[*Image Source: Wikimedia Commons*]

All the resistors and resistances you meet in AP Physics follow a relation called *Ohm's Law:*

$$V = IR.$$

In this equation, $V$ is the potential difference across the circuit element, $I$ is the current through the element, and $R$ is its resistance. Circuit elements that follow this law are called *Ohmic.*

Remember we said that $V$ is the change in potential energy per charge. When we multiply by current, we get the change in potential energy per time:

$$\frac{\Delta energy}{charge}\frac{charge}{time} = \frac{\Delta energy}{time}$$

# Circuits Review Cont.

Since power is energy per time, we now have a formula for the *power dissipated by a resistor:*

$$P = VI = I^2R = V^2/R,$$

The last two expressions come from substituting *V* = *IR* in various forms in the leftmost equality. The function of the battery is to compensate for this energy loss by transforming its chemical energy into electrical energy, which is eventually dissipated in the form of heat by the resistor(s) according to the formula above. This is why batteries get used up!

### Combining Resistances

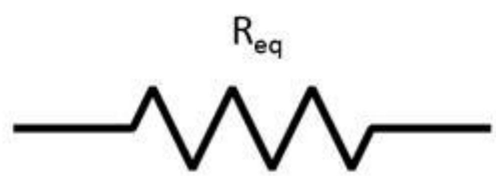
On the AP exam, you'll see resistors connected to each other in different combinations. All traditional combinations can be broken down into simpler combinations of two types: series and parallel.

You'll almost certainly be asked to find the "equivalent resistance" of a combination of resistors. "Equivalent resistance" stands for the resistance of one resistor which would give the same current under the same voltage difference as the original combination does, or equivalently, the resistance of one resistor which would give the same voltage difference under the same current. All we need to derive the formula for resistor combinations are Ohm's Law, *V* = *IR*, and Kirchhoff's laws.

# Circuits Review Cont.

**Resistors in Series**

Resistors in series are connected in the same current pathway; you could think of them as two waterwheels on the same river. Below are two series resistors and the desired equivalent resistance.


The same current *I* passes through both $R_1$ and $R_2$, so the voltages across these resistors are

$$V_1 = IR_1, V_2 = IR_2.$$

The total voltage across the combination is

$$V_1 + V_2 = I(R_1 + R_2).$$

# Circuits Review Cont.

We want the equivalent resistance to give the same voltage as the total voltage across the combination:

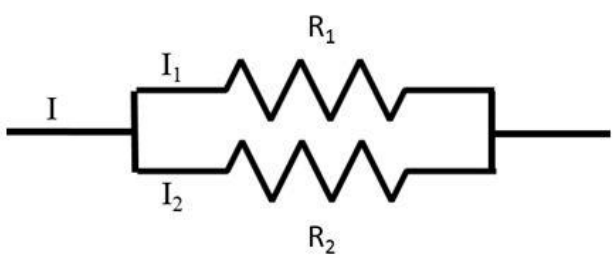
$$V_{eq} = V_1 + V_2 = I(R_1 + R_2).$$

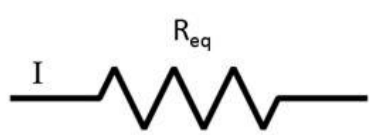
Since $V_{eq} = IR_{eq}$, we have $R_{eq} = R_1 + R_2$. Extending this to an arbitrary number of resistors in series, the equivalent resistance of series resistors is

$$R_{eq} = R_1 + R_2 + R_3$$

**Resistors in Parallel**

Resistors in parallel are connected in separate branches that join together before and after the current passes through the parallel resistors:




In the figure above, a total current I separates into smaller currents $I_1$ and $I_2$ which pass through resistors $R_1$and $R_2$, respectively.

# Circuits Review Cont.

By Kirchhoff's junction rule,

$$I = I_1 + I_2.$$

By Kirchhoff's loop rule on the loop consisting of resistors 1 and 2,

$$V_1 = V_2, \text{ or}$$

$$R_1 I_1 = R_{12} I_2$$

$$I_2 = R_1 I_1 / R_2.$$

Substituting this into Kirchhoff's junction rule, we obtain

$$I = I_1 (1 + R_1/R_2).$$

The voltage across the equivalent resistance is by definition equal to either the voltage across resistor 1 or resistor 2 (they're equal):

$$R_{eq} I = R_1 I_1.$$

Combining this with the previous equation, we have $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$. Extending to an arbitrary number of resistors, the equivalent resistance of parallel resistors is given by:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

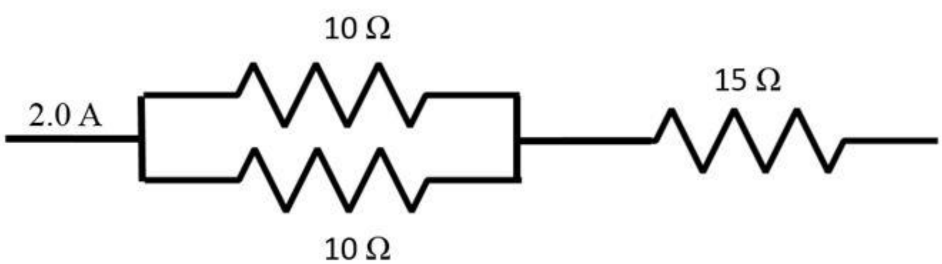
# Circuits Review Cont.

To solve for the equivalent resistance algebraically, this equation tells you to add the reciprocals of the parallel resistances and take the reciprocal of the sum. This is the desired equivalent resistance.

Here's an example problem that involves both parallel and series resistors.

**Equivalent Resistance**

*A 2A current enters the resistor combination below:*




*(a) Find the current through each resistor.*

*(b) Find the power dissipated by each resistor.*

*(c) Find the equivalent resistance of the combination.*

*(d) Find the total power dissipated by this combination.*

**Solution:**

(a) All of the current must pass through the 15Ω resistor, so the current through it is 2.0*A*. The parallel combination is composed of two identical resistances, so the current through either of them is 1.0*A*. If these resistances were not identical, you would have to use Kirchhoff's laws to set up the equations

$$I = I_1 + I_2, R_1 I_1 = R_2 I_2,$$

# Circuits Review Cont.

and then solve for $I_1$ and $I_2$.

(b) Using $P = I^2R$ for each of the three resistors, we find

$$P_{10\Omega} = (1.0A)^2(10\Omega) = 10W,$$

$$P_{15\Omega} = (2.0A)^2(15\Omega) = 60W.$$

(c) The equivalent resistance of the parallel combination is given by

$$\frac{1}{R_{parallel}} = \frac{1}{10\Omega} + \frac{1}{10\Omega}, \text{ or } R_{parallel} = 5\Omega.$$

The equivalent resistance of the entire combination is given by summing the resistance of the first combination with the remaining resistance in series:

$$R_{eq} = 5\Omega + 15\Omega = 20\Omega.$$

(d) Since voltage and current are identical in equivalent resistances and resistance combinations, power is identical as well. We can just use the power formula

$$P = I^2R_{eq} = (2.0A)^2(20\Omega) = 80W.$$

Of course, this is equal to the sum of the powers dissipated by the three resistors in part (b).

# Circuits Review Cont.

**Capacitance (Physics 2 Only)**

A capacitor is a device which consists of two metal *plates* separated by a small distance, which might contain an insulator such as paper or ceramic.

Below is the symbol for capacitance on the AP Physics 2 Exam; you can see the symbolic representation of the two plates:

*Image Source: Wikimedia Commons*

A capacitor has the *capacity* to store charge: one plate is positively charged and is at a higher potential; the other plate is negatively charged and is at a lower potential. The higher the capacitance, the more charge it can store for a given voltage difference. We call this ratio the capacitance, which is denoted by the capital letter C.

$$Q = CV.$$

Q represents the magnitude of charge on either plate and V represents the potential difference between the two plates. Capacitance is measured in Coulombs per Volt; physicists call this unit the *Farad*:

$$1F = 1C/V.$$

# Circuits Review Cont.

Think about the equation $Q = CV$. If $V$ is constant, then so is $Q$. Since no change in charge means no flow of current,

No current flows in or out of a fully charged capacitor.

Current flows only if the capacitor is charging or discharging. You won't have to worry about this for the AP Physics 2 Exam: the questions cover only the steady-state behavior of capacitors – when they are fully charged or not charged at all.

Similarly, to how resistors *dissipate* energy, capacitors *store* energy. The formula for stored energy in a capacitor are

$$U = \frac{CV^2}{2} = \frac{Q^2}{2C} = \frac{QV}{2}.$$

If you memorize one formula, you can get the other two by substituting various forms of the definition of capacitance, $Q = CV$.

### Combining Capacitance's (Physics 2 Only)

The laws for finding equivalent capacitance's are the reverse of those for resistances. The derivations are quite similar so *I* won't derive the formulas for equivalent capacitance's, but here they are:

**Capacitors in Series**

$$\frac{1}{C_{eq,series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

**Capacitors in Parallel**

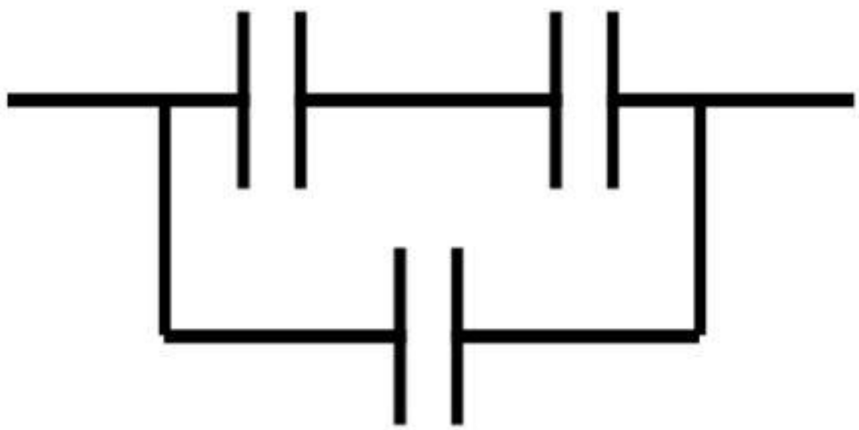
$$C_{eq,parallel} = C_1 + C_2 + C_3$$

# Circuits Review Cont.

Let’s do an example problem similar to one you might encounter on the AP Physics 2 Exam.

**Equivalent Capacitance**

*In the diagram below, each capacitor has a capacitance of 10mF, and the voltage across the combination is 5.0V.*



*(a) Find the voltage across each capacitor.*

*(b) Find the charge on each capacitor.*

*(c) Find the equivalent capacitance.*

*(d) Find the total energy stored in the circuit.*

**Solution:**

(a) The voltage across both branches must be the same, by Kirchhoff’s loop rule. Since the capacitance’s of the two capacitors in the top branch are equal, both have a potential difference of *2.5V*. The potential difference across the bottom capacitor is *5.0V.*

# Circuits Review Cont.

(b) Using the equation *Q* = *CV*, we find

$$Q_{top} = (10mF)(2.5V) = 25mC,$$

$$Q_{bottom} = (10mF)(5V) = 50mC.$$

(c) Using the series addition rule, the equivalent capacitance of the top branch is given by

$$\frac{1}{C_{top}} = \frac{1}{10mF} + \frac{1}{10mF}, \text{ or } C_{top} = 5mF.$$

Using the parallel addition rule on both branches, $C_{eq} = 5mF + 10mF = 15mF.$

(d) We know the equivalent capacitance of the combination and the total voltage across it, so by the energy formula,

$$U = \frac{CV^2}{2} = \frac{(15mF)(5.0V)^2}{2} = 0.19J.$$

(d) We know the equivalent capacitance of the combination and the total voltage across it, so by the energy formula,

# Circuits Review Cont.

## Wrapping Up Circuits for the AP Physics 1 and 2 Exams

Here are important equations you should know for the AP Physics 1 and 2 Exams.

**Kirchhoff's Junction Rule**

*Current in = current out*

**Kirchhoff's Loop Rule**

*Sum of potential differences around a loop = 0*

**Ohm's Law**

$$V_R = IR$$

**Power Dissipated by a Resistor**

$$P = VI = I^2R = V^2/R$$

**Series Equivalent Resistance**

$$R_{eq} = R_1 + R_2 + R_3$$

**Parallel Equivalent Resistance**

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

# Circuits Review Cont.

**Definition of Capacitance**

$$Q = CV$$

**Energy Stored in a Capacitor**

$$U = \frac{CV^2}{2} = \frac{Q^2}{2C} = \frac{QV}{2}$$

**Series Equivalent Capacitance**

$$\frac{1}{C_{eq,series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

**Parallel Equivalent Capacitance**

$$C_{eq,parallel} = C_1 + C_2 + C_3$$

# How to Make Effective AP Physics Flashcards

*Image Source: Flickr*

Flashcards can be extremely helpful for studying for the AP Physics exams. While there is very little vocabulary that students need to know for the exam, there are several formulas and equations that students need to know to solve the problems of the multiple choice and free response sections.

When using flashcards for formulas and equations, students should start by putting the formula that they are trying to learn on one side and an AP Physics problem that would use that formula on the other. While the formula names can be helpful for remembering the formula, you are better off putting a relevant AP problem on the other side of the flashcard because it trains you to associate a formula with a specific type of problem. This cuts down on the time you will spend trying to remember which formula should be used for a problem on the actual exam, and makes more effective AP Physics flashcards.

# How to Make Effective AP Physics Flashcards Cont.

The following are some examples of flashcards with formulas and equations for the different AP Physics exams. The formula or equation will be on the back, and the relevant problem on the front.

**AP Physics C – Mechanics:**

Front – What is the kinetic energy of the $5g$ ball when it is moving at $5m/s$?

Back – $K = (\frac{1}{2})mv^2$

**AP Physics C – Electricity and Magnetism:**

Front – What is the total capacitance of the circuit?

Back – $C_n = C_1 + C_2 + C_3 + \ldots$

**AP Physics 1:**

Front – How fast is the bus moving at $t = 3$?

Back – $Vx = Vxo + Axt$

**AP Physics 2:**

Front – How far has the bus gone at $t = 3$?

Back – $x = xo + Vxot + \frac{1}{2}Axt^2$

# How to Make Effective AP Physics Flashcards Cont.

Flashcards can also be used for the vocabulary on the AP Physics exams. Most students don't realize that there are vocabulary words that you should know for the exam. These vocabulary words can be found in the free response section of the exam, and will help you to understand what the question is asking. For example, for the AP Physics C exams, you should be able to define the words "justify", "explain", "determine", and "derive" within the context of the exam. Many of these words seem to be synonyms of each other, and in some cases they are. However, in some cases they are not.

The following are some examples of flashcards with vocabulary for the different AP Physics exams. The vocabulary word will be on the back, and the definition on the front.

**AP Physics C:**

Front – begin with a fundamental equation and use calculations to come to an answer

Back – Derive

**AP Physics 1 or 2:**

Front – some work is a good idea, but you do not need to show your work

Back – determine

While creating flashcards is important, the effectiveness of the flashcards is penultimate, and is determined by how you use them. When using flashcards to study, there are two important things that you can do to get the most out of your flashcards.

# How to Make Effective AP Physics Flashcards Cont.

## 1. Take Note of Wrong Answers

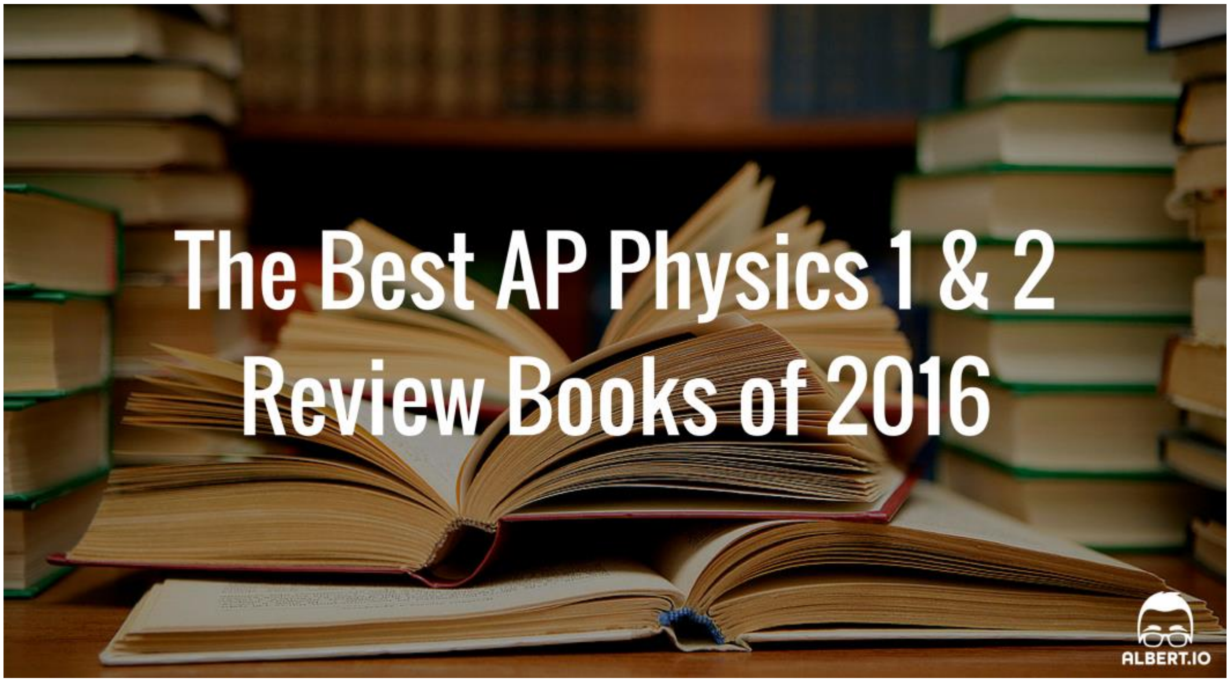
When going through your flashcards, make separate piles for the cards that you have answered correctly and the cards you have answered incorrectly. Once you have made it through the entire pile, take the pile of cards you got wrong and review the material, then do them again. Do this until you no longer get any cards wrong.

## 2. Invite Your Friends

If you know other people studying for the same AP Physics exam as you, invite them to study with you using the flashcards. When you study with other people, your peers can explain topics you may not understand in a way that is more understandable to you. Also, explaining your rationale behind an answer to other people helps you to make sure that you completely understand the material.

For those who are reviewing in the days before the exam and do not have enough time to make flashcards for all of the material on the exam, there are resources that you can use to get flashcards. Flashcards are available both for purchase and online to most student. If you'd like to purchase your flashcards, most of the major prep book companies make box sets of AP Physics flashcards for every exam they make a prep book for. If you'd like to get your flashcards online, there are websites, such as Quizlet, where other students have made flashcards for a variety of subjects, including the AP Physics exams. These flashcards are available to anyone on the website, and the site can quiz you on any set of flashcards in a variety of manners. Of course, making your own flashcards is always a better idea if time permits, because it allows you to customize your flashcards to your needs.

# The Best AP Physics 1 & 2 Review Books of 2016




If you are planning on taking the AP Physics exam this spring, it's best to start preparing as early as possible. But what are you supposed to do if your class notes and textbooks are too much to sift through? Supplementing your study with a review book can help make sure you are focusing on all of the right content that will be on the exam.

The AP Physics 1 & 2 exam was changed during the 2014-2015 school year. So what's the best way to prepare for the new test? You can't use the old practice books…But how will you know which new books are reliable and can provide you with the practice you need? Luckily, we're here to assist you.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

Here are some things to pay attention to when selecting a book:

- Breadth and scope of the book
- Organization
- Validity of sample questions and answers given
- Style of the sample questions (computational versus conceptual)
- Additional resources (online resources, apps) provided

We know you're daunted by the amount of content you have to review, but in case your physics teacher has not supplied you with the College Board's outline of the exam content for AP Physics 1 & 2, here it is:

**AP Physics 1**

- Kinematics
- Dynamics: Newton's laws
- Circular motion and universal law of gravitation
- Simple harmonic motion: simple pendulum and mass-spring systems
- Impulse, linear momentum, and conservation of linear momentum: collisions
- Work, energy, and conservation of energy
- Rotational motion: torque, rotational kinematics and energy, rotational dynamics, and conservation of angular momentum
- Electrostatics: electric charge and electric force
- DC circuits: resistors only
- Mechanical waves and sound

**AP Physics 2**

- Thermodynamics: laws of thermodynamics, ideal gasses, and kinetic theory
- Fluid statics and dynamics
- Electrostatics: electric force, electric field and electric potential
- DC circuits and RC circuits (steady-state only)

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

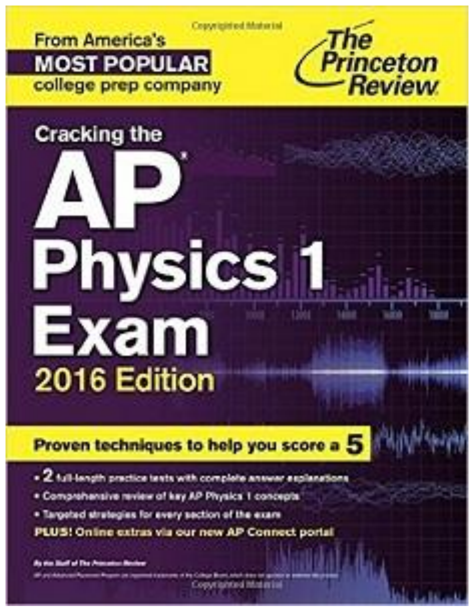
- Magnetism and electromagnetic induction
- Geometric and physical optics
- Quantum physics, atomic, and nuclear physics

When choosing your review book you need to consider some things that will help you personalize your studying. Are you cramming or studying leisurely? What subjects are you weak at? Do you need lots of sample questions? What's most important to you? Keep these in mind because not every student learns the same way!

We are going to review 4 books for you to help narrow down your options.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

[Cracking the AP Physics 1 & 2, 2016 Edition]




These 416 and 400-page books claim to provide students with techniques to avoid traps on the exam, make educated guesses when stumped, and manage the pace of the test so as to bolster the student's test-taking techniques as come standard with Princeton Review books. The book claims to be updated for the 2016 AP Physics exam since its last edition came out (worryingly?) before the first new AP Physics exam. Often Princeton Review books are the gold standard for test preparation, but you always have to be careful that they don't cover too much or don't cover enough!

It covers topics such as kinematics, dynamics, Newton's laws, work, energy, rotational motion, electrostatics, DC circuits, mechanical waves, sound and more.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

**Here's what makes this Princeton Review book good:**

- The book is complete with two full-length practice tests with explanations of the solutions as well as practice drills at the end of each chapter and walk-throughs of sample questions in each section.

**But, before you go ahead and buy this book you should know about the book's pitfalls.**

- The book largely borrows its content from its previous test on the Physics B Exam, almost verbatim, with the only differences being deletions.

- There are also some Physics B topics accidentally left in, such as the modeling of waves using trigonometric functions, and the Doppler effect.

- The rotational motion section has glaring omissions, such as not discussing angular momentum or rotational kinetic energy.

- The introduction of the book describes the new test format but doesn't provide practice questions that correlate.

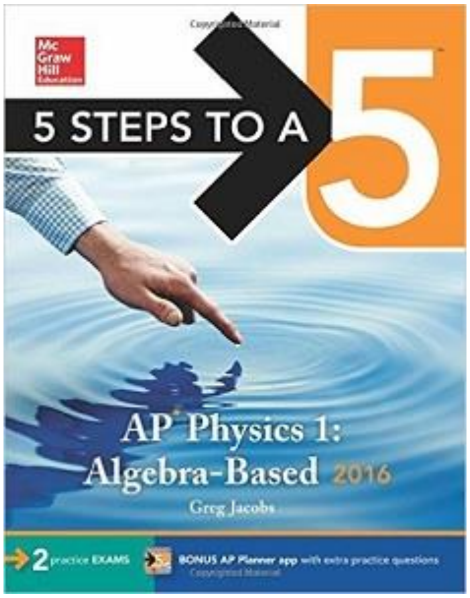
This book is probably useful for students in college looking to brush up on their introductory physics, but that doesn't necessarily make it good as a test prep material. Certainly do not buy this if you're intending to use it as a cram tool.

Ouch! Lots of negatives!

**GRADE: D**

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

[5 Steps to a 5 AP Physics 1 & 2 2016]




These 304 and 352-page McGraw-Hill test prep books, complete with 2 practice exams are a bit more promising. The 2016 edition is the same as the 2015 edition except for the addition of another practice test. Not much of an update, but hey, the more practice, the better!

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

**The good part is that:**

- The book is quite concise and for that reason is well-suited to a student that needs to cram in a short amount of time.

- The content is pretty spot-on with the requirements of the new exam.

- The author will hone your test-taking skills. You need to know that getting a 5 on the AP exam is not all about having an encyclopedic knowledge on high school AP Physics. This will set you straight.

However, if you're looking for one of those books that are chock-full of practice problems, this might not be so helpful. Also, if you're one of those star physics students that's looking for some practice problems on the hardest questions, this might not be the best either.

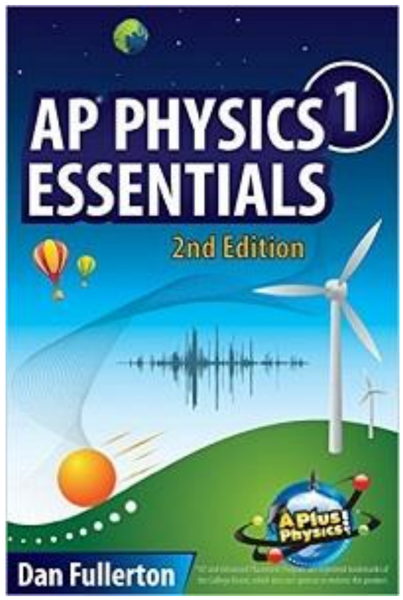
That being said, one of the perks of this book is the access to McGraw-Hill's AP planner app, which lets you customize your study plan on your phone. If you and your phone are inseparable, then look no further! The author of the book is also an AP Physics teacher in Virginia, adding legitimacy to the content.

Looking good!

**GRADE: B+**

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

AP Physics Essentials 1 & 2




These 406 and 336-page books are touted as easy to read. It doesn't claim to be the solution to all your physics problems though. The book covers the "bare essentials" and lets the curious student seek out classroom opportunities to go through the more challenging problems. This will get you back on track if you're stuck on some of the more fundamental topics. The topics include: kinematics, dynamics, momentum, impulse, gravity, uniform circular motion, rotation, work, energy, power, mechanical waves, sound, electrostatics, and circuits. It's a good book to begin with if merely the mentioning of the word "physics" sends cold shivers down your spine.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

**We come to the best parts about this book:**

- Just like the McGraw-Hill book, this test prep book takes advantage of online resources and allows you to integrate with aplusphysics.com. If you love scouring forums, watching videos, animations (cool!) and tackling further supplemental problems, then look no further, this might be the book for you! AP Physics Essentials 1 & 2 only has 90 AP-style problems, but you can always refer to the website to drill yourself some more.

- The author of this book is also a physics teacher at a high school with a particular distinction being that he was named a NY State Master Physics teacher in 2014.

**But, does that mean the test prep material he makes is gold? Well, one notable issue is that:**

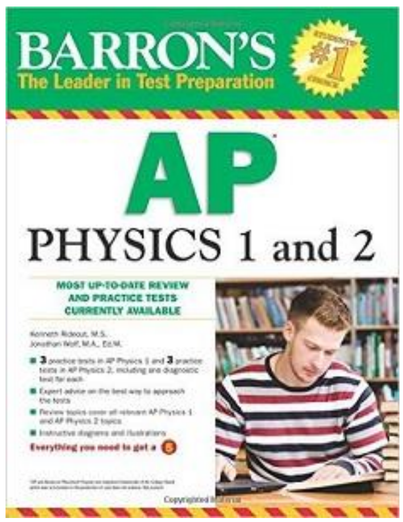
- Some of the practice problems focus more on calculation, whereas the content of the new AP Physics exam is more conceptual. Food for thought…

Not too bad!

**GRADE: B-**

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

[Barron’s AP Physics 1 and 2]




This hefty 528-page book purports to organize itself around the 7 “Big Ideas” of physics. If you’re a conceptual person, this book may help you organize the myriad of topics into a more coherent list. If you looked at the College Board list above and panicked, thinking about all of the topics you were unfamiliar, sometimes having a good organizational way of thinking about the subject allows you to digest it better.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

**Here's what's good:**

- This exam contains four practice tests
- There are even diagnostic tests to let you know what you need to brush up. If you're rushed for time, take one of these diagnostic tests; it might let you know that you don't know a subject as well as you thought.
- If four practice tests aren't enough, you can buy the test book with a CD ROM (do you still use these?) that has two more tests that are automatically graded.

The topics covered are vectors, kinematics, forces and Newton's laws of motion, energy, oscillatory motion, waves and sound, gravitation, impacts and linear momentum, rotational motion, electrostatics, electric circuits, magnetism and electromagnetism, physical optics, geometrical optics, fluids, thermodynamics, 20th-century physics. Sounds like it covers everything? Well, not quite.

**Here are the shortcomings of this book:**

- The book skips some topics including (but not limited to) rotational inertia, angular trajectory, voltmeters, and standing waves.
- The most glaring error in this textbook is the inadequacy and sometimes downright falsity of the practice test answers (most notably in thermodynamics). For this reason, it's not very popular with physics teachers. So, don't take the answers too seriously and confer with your physics teacher if necessary.

Hmm… Maybe not such a great choice!

**GRADE: D+**

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

## So Which One is the Best AP Physics 1 & 2 Review Book?

Well, you want the verdict. Of course, each book suffers from a little setback, but we can separate them into two categories: **promising**, and **troubling**.

Where do you think *Cracking the AP Physics 1 & 2* belongs? If you said **troubling**, you're spot on. When preparing for a test (and especially in the short-term) you need to know that the content in the book is identical with the content on the exam. The authors of this book have copied from previous editions of their own books used for other exams. Copying and pasting is not a good model for releasing a new book, it's just lazy, which is not what you should be.

What about *5 Steps to a 5 AP Physics 1 & 2*? **Promising**, definitely! The content is right and accurate. Their only downside is the scarcity of problems, which is helped by the inclusion of the app.

Okay, and what about *AP Physics Essentials 1 & 2*? You think **promising**? We agree, at least for most students. The questions will sometimes lead you to believe the actual exam will have lots of calculations, which isn't quite right. It's also not the right book for the star student, but it does pretty much achieve what it sets out to do.

And last, but not least, *Barron's AP Physics 1 and 2*? **Troubling** is right! The best part about the book is the amount of questions, just like the Cracking the AP Physics book, but there are too many glaring errors and the physics sometimes is just wrong! Only use if you work through with the guidance of your teacher.

# The Best AP Physics 1 & 2 Review Books of 2016 Cont.

## Final Verdict

| Book Title | Biggest Pro | Biggest Con | Perk | Grade |
|---|---|---|---|---|
| **Cracking the AP Physics 1 & 2** | **Lots of sample problems (in the text, after the text and at the end) with explained solutions** | **Did not change much from old AP exam format** | **N/A** | D |
| **5 Steps to a 5 AP Physics 1 & 2 2016** | **Closely follows exam content** | **Short and terse (only 2 practice exams)** | **McGraw-Hill AP Planner app** | B+ |
| **AP Physics Essentials 1 & 2** | **Focuses on fundamentals, better for struggling students** | **Questions focus too much on calculation, not on conceptual questions** | **Access to aplusphysics.com** | B- |
| **Barron's AP Physics 1 and 2** | **Four practice exams** | **Mistakes in the physics and answers** | **N/A** | D+ |

The best AP Physics review book series of 2016 to date is *5 Steps to a 5 AP Physics*. Not only is the content of the chapters and sample problems more accurate, but they give you access to the resources of an app. In my opinion, you should look into buying *AP Physics Essentials 1 & 2* additionally if you're the struggling physics student.

**Have a great review book that's not on our list? Let us know!**

# Ready to Score Higher?

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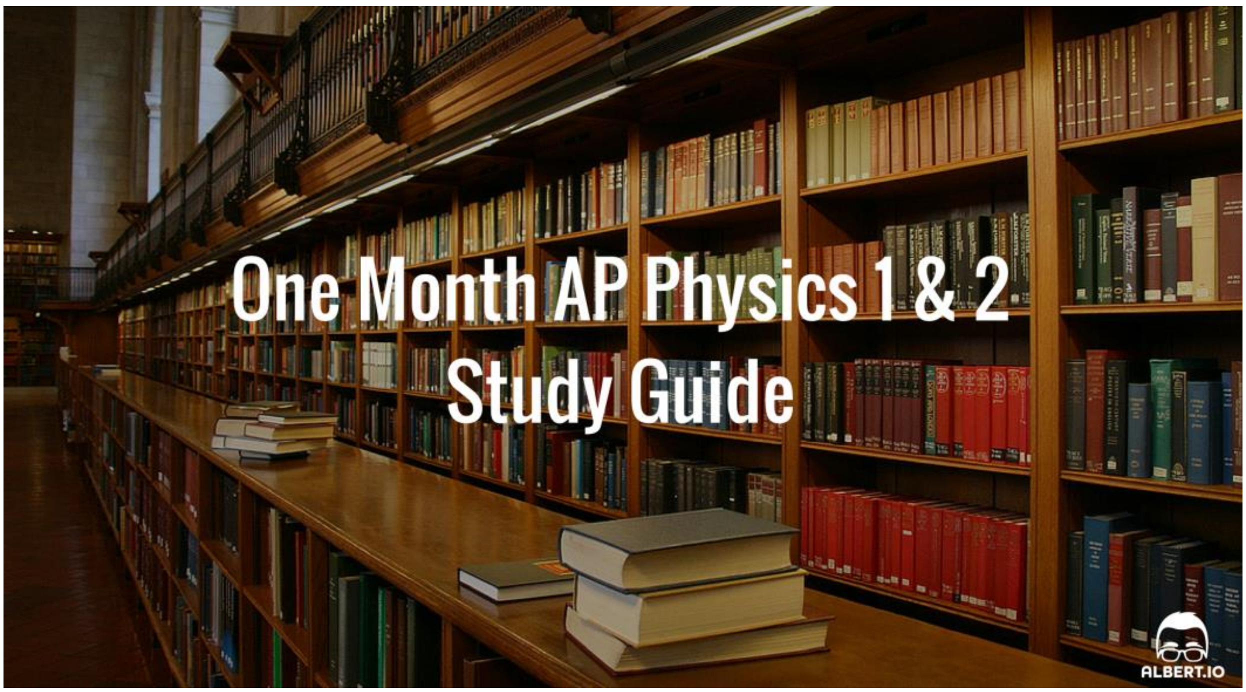
Start Practicing

# One Month
# AP Physics 1 & 2
# Study Guide




So it's down to the wire, and you're not sure where to start your review for the AP Physics exam. With the test just around the corner, you may be worried about how you are going to study it all! Don't fret, we're here to make sure you perform better and more confidently on the exam. The best way you can score on the exam is by preparing well and making sure you stay healthy and get enough sleep. Can't stress that one enough!

# One Month AP Physics 1 & 2 Study Guide Cont.

This daily study guide will outline what you can accomplish to get you that much closer to that elusive 5! If you've waited until the last moment, this study guide will be intensive, but it is invaluable to you at this point! Be prepared to devote a few hours a day, six days a week (hooray, you have one day off!), with the natural assumption that you will have more time on the weekends. But, if you stick to the plan, you'll be that much closer to the score you want to get. If you have more than 1 month to go until test day, then this rigorous schedule can be relaxed a bit. Good luck!

Oh, and one more thing, keep in mind all of the topics that will be covered on the exam. If you are taking only Physics 1, stick to the Physics 1 material! For reference, here is the breakdown of topics from the CollegeBoard:

**AP Physics 1**

- Kinematics
- Dynamics: Newton's laws
- Circular motion and universal law of gravitation
- Simple harmonic motion: simple pendulum and mass-spring systems
- Impulse, linear momentum, and conservation of linear momentum: collisions
- Work, energy, and conservation of energy
- Rotational motion: torque, rotational kinematics and energy, rotational dynamics, and conservation of angular momentum
- Electrostatics: electric charge and electric force
- DC circuits: resistors only
- Mechanical waves and sound

# One Month AP Physics 1 & 2 Study Guide Cont.

**AP Physics 2**

- Thermodynamics: laws of thermodynamics, ideal gases, and kinetic theory
- Fluid statics and dynamics
- Electrostatics: electric force, electric field and electric potential
- DC circuits and RC circuits (steady-state only)
- Magnetism and electromagnetic induction
- Geometric and physical optics
- Quantum physics, atomic, and nuclear physics

**What you will need:**

- **Albert.io** AP Physics 1 & 2 practice questions (700+ multiple-choice questions)
- Flashcard site like **Quizlet** (otherwise we will create our own)
- Plenty of paper (notebooks) and writing utensils (it's time to break out those highlighters and get coloring)
- AP Central Free Response Questions (**Physics 1** & **Physics 2**) (pdf reader required)
- **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book**
- Your AP Physics 1 & 2 textbook
- A useful Youtube channel called **Flipping Physics** and/or **Dan Fullerton** (for Physics 1)
- Another useful Youtube channel from a woman named **Yau-Jong Twu** (for both Physics 1 & 2)
- Your teacher, family, friends (aka your support group)

# One Month AP Physics 1 & 2 Study Guide Cont.

**Other Materials**

- Supplemental reading material
- Supplemental online videos **Bozeman Science**
- Bonus practice questions from a test review book (such as 5 Steps to a 5 AP **Physics 1** & **Physics 2** 2016 Ed. containing two practice exams)

**Some Notes**

- The Physics 1 exam is at 12:00 pm on May 3, 2016
- The Physics 2 exam is at 12:00 pm on May 4, 2016

Before we really get started, keep the following in mind. Ideally, all questions should be done in under exam-like conditions. Seriously! Set a timer, don't get distracted by your phone, and don't use your computer to look up things you forget. But, when reviewing, you are welcome to go through this one-month study guide in a group, or by yourself if that's how you study better. Please cater this study guide to your needs. If you are going to take the Physics 1 exam, follow the study guide below for Physics 1. If you are going to take both exams, follow the study guide below for Physics 1 & 2.

The next important thing to keep in mind is your health. It is very difficult to perform your best if you are lacking in sleep or if you don't eat right. Try to balance your nutrition, sleep well, and exercise! Stress will not make the exam any easier but will take a toll on your health so make sure to eat well, sleep well, and exercise well!

Also, this study guide is going to assume the final review day is on the weekend. The final day, therefore, will be a bit long, so feel free to break it up into two days if you want. We don't want you to cram! Did I mention not to stay up late cramming the night before? Make sure to get plenty of rest the night before the exam.  You have done all you can to prepare so get some rest and be confident.

Alright, let's begin!

# One Month AP Physics 1 & 2 Study Guide Cont.

**WEEK 1**

The purpose of this week is to get you used to:

1. Doing test questions from all the topics that will be covered on the exam

2. Reviewing concepts from test questions

3. Compiling flashcards

4. Becoming proficient in the two most challenging topics for you

**Day 1**

**Physics 1**

In order to start your studying, we need to figure out what subjects you need to focus on. Let's start by trying some of **Albert.io**'s multiple-choice questions. You will see that there are 12 sections. The first 5 are for Physics 1 only, the next 2 are for both Physics 1 and Physics 2, while the last 5 are for Physics 2. Today, we will do some sample problems from the first three sections: "Motion in 1 and 2 Dimensions", "Forces, Circular Motion, and Gravitation", and "Energy and Momentum". Do three questions from each subsection (for a total of 36 questions), choosing one *easy* question, one *moderate* question, and one *difficult* question (if possible). For example, in the first subsection of "Motion in 1 and 2 Dimensions" choose three questions from the subsection "Displacement, Velocity, and Acceleration" (remember, 1 *easy*, 1 *moderate*, and 1 *difficult*). Even though the system will keep track of what you got right and wrong, write down which ones gave you trouble and why. Read the explanations and write down in your notebook *anything* you did not think of yourself, even for the questions you got right. Do not move on to any other questions for the time being.

# One Month AP Physics 1 & 2 Study Guide Cont.

*Note: Without full access to Albert.io, you will not be able to view the difficult questions. For this review, it is recommended that you get full access to different levels of questions.*

Be honest with yourself and your scoring, keeping track of what level of questions you got wrong in which subjects. With the information you have, review the sections corresponding to the questions that you got wrong and write copious notes! There might be a lot you have to review for the entire test, but just take it one step at a time and review the material for today. If you run out of time, mark the place where you left off and you can return to it later. Perhaps your score will leave you slightly disheartened, but don't worry, this is the first day of your studying! Keep organized, and keep reviewing! An incorrect answer, while frustrating, makes your review easier, because it will tell you exactly what you don't fully understand.

Begin compiling your own flashcards for unfamiliar terms and concepts. Try and find a concept from each question that you can quiz yourself on later using your flashcards, particularly for each question you got wrong. For example, on one side of the flashcard, write "Work is" and on the other side write "Force times distance" and draw a graph of force (y-axis) versus distance (x-axis), then shade the area between the graph and the x-axis. This way, every time you review this term, you'll remember both the simple mnemonic formula, as well as a visual cue. Flashcards are a good way of condensing a complicated, long topic into a few points (and a graph or picture is often useful)

**Physics 2**

Let's begin. The first thing we need to do is find out which Physics 2 subjects you need to review. Start by doing some of **Albert.io**'s multiple-choice questions. There are 12 sections. The first 5 sections are only for Physics 1, the subsequent two are for both Physics 1 & 2 (the questions are clearly divided between Physics 1 & 2), and the remaining 5 are for Physics 2. We are going to go through some problems from the following sections: "Electrostatics", "Electric Circuits", and "Fluid Mechanics" and "Thermal Physics".

# One Month AP Physics 1 & 2 Study Guide Cont.

Pick three questions from each subsection for Physics 2 (for a total of 33 questions), choosing one *easy* question, one *moderate* question, and one *difficult* question. For example, in the second subsection of "Electrostatics" choose three questions from the subsection "Electric Force and Coulombs Law" for Physics 2 (remember, 1 *easy*, 1 *moderate*, and 1 *difficult*). The system will keep track of which questions were answered right and wrong, but you should take notes on which problems were difficult for you and why. Check out the explanations and jot down in your notebook anything you hadn't thought of, even for the questions you answered correctly. You may be tempted to, but please refrain from moving on to any other questions for now.

*Note: Without full access to Albert.io, you will not be able to view the difficult questions. For this review, it is recommended that you get full access so that you will be able to access the difficult questions.*

– Keep track of what you got wrong in which subjects and which level. Review the pertinent sections based on the questions that you got wrong and write lots of notes! Don't worry! I know you are daunted by the amount of material you think you have to review for the test, but just take it one step at a time. If you run out of time, jot down where you left off and return to it later. It's possible that your score results will make you feel like you're inadequately prepared, but fear not (yet), this is only the first day! Be honest with yourself about your level of knowledge and keep your study materials organized and reviewing your notes! An incorrect answer, while perhaps causing you consternation, will make your review easier, because it will pinpoint precisely where you need to review. Typically, Physics 2 questions are more challenging than Physics 1 questions. You're going to have to push yourself a bit more to get that 5!

Time for flashcards! We're going to use them for unfamiliar terms and concepts. Try and figure a concept from every question that you can use to quiz yourself on later, especially for each question you got wrong. For example, on one side of the flashcard, write "Conservation of Mass Flow Rate" on one side and on the other side write "In an ideal liquid, the same amount of mass moves through a given area per time".

# One Month AP Physics 1 & 2 Study Guide Cont.

Then draw two pictures, the top picture showing a medium-diameter pipe leading to a large-diameter pipe, and the bottom picture showing the same medium-diameter pipe leading to a small-diameter pipe.  Next to the top picture write "slower" by the large-diameter pipe, and next to the bottom picture write "faster" by the small-diameter pipe. This way, every time you review this term, you'll remember both the definition, as well as a neat visual cue to help when answering questions. (Oh! And writing down a simple sample calculation would be a great idea too!)

You're doing great so far! The first day is under your belt. Do a little each day and pretty soon it'll be done before you know it.

**Day 2**

**Physics 1**

Run through your flashcards from yesterday and note which ones you got incorrect. If you got one wrong, hit the books and take notes. If you didn't finish reviewing your concepts from yesterday, this is a good time to finish where you left off.

Go to **Albert.io**. We are going to continue going through topics today! You are going to choose 3 questions (again, 1 *easy*, 1 *moderate*, and 1 *difficult*) from each subsection of "Rotational Motion", "Oscillation, Waves, and Sound", "Electrostatics" and "Electric Circuits" (Physics 1 *only*) for a total of 36 questions. Write down what you got wrong and why.

Hit the books and review the sections that pertain to the questions you went through. If you run out of time, mark where you left off, because we'll continue tomorrow.

Compile flashcards for the terms and concepts from this section. Again, try to get at least one concept out of each question asked!

# One Month AP Physics 1 & 2 Study Guide Cont.

**Physics 2**

Review the flashcards you made yesterday. If you get one wrong, hit the books and take notes. If you didn't finish reviewing your concepts from yesterday, this is a good time to finish where you left off.

Go to **Albert.io**. You are going to choose 3 questions (again, 1 *easy*, 1 *moderate*, and 1 *difficult*) from each subsection of "Magnetic Forces and Electromagnetic Induction", "Light and Optics" and "Atomic and Nuclear Physics" for a total of 33 questions. Write down what you get wrong and why in your notebook.

Open your textbook and peruse the sections that are related to the questions you just went through. Just like yesterday, if you run out of time, don't worry, because we'll continue tomorrow.

Compile flashcards just as you did before for the terms and concepts from this section. Again, try to find at least one concept in each question asked (you can mouse over the tags below the Albert.io questions to help you figure out what is being tested by that question)!

**Day 3**

**Physics 1 & 2**

Run through your flashcards from yesterday and be honest about which ones you didn't know. If you got one wrong, hit the books and take notes. Make sure to finish review where you left off yesterday if you didn't finish.

Pick the 10 subsections that gave you the most trouble in the last couple of days. Choose three questions from each subsection, for a total of 30 questions, preferably of different difficulties. Then, write down what you got wrong and why.

# One Month AP Physics 1 & 2 Study Guide Cont.

Review the sections in your textbook that pertain to the questions you went through. If you run out of time, mark where you left off and start there tomorrow

Compile flashcards for the terms and concepts from this section. Again, try to get at least one concept out of each question asked.

**Day 4**

**Physics 1 & 2**

Once again it's time for flashcards. You can add hints for yourself if you find that you keep missing particular cards. You will be able to knock them all out soon enough.

Pick the 10 subsections that gave you the most trouble in the last couple of days and do at least 3 questions from each subsection. Try to vary the difficulty and don't only pick easy questions. Then, write down what you got wrong and why.

Review the sections in your textbook that pertain to the questions you went through. You can make note of where you left off, if you don't finish.

Time to compile flashcards for the terms and concepts from this section. Again, try to get at least one concept out of each question asked!

**Day 5**

**Physics 1 & 2**

Today we will start with flashcards again. Test yourself and take notes if you got one wrong. Don't forget to finish up from yesterday if you weren't able to finish all of your textbook review.

Go to **Albert.io** and do 10 questions randomly. We are going to start trying to keep your problem solving to a reasonable amount of time.

# One Month AP Physics 1 & 2
# Study Guide Cont.

Right now, give yourself no more than 2 minutes per problem. After you finish each problem, just like we did before, make flashcards for the main concepts from the problems, especially those which you got wrong!

Alright, now is the time to become an expert in a section that you find most difficult. For example, if you're a Physics 1 student, maybe you most often get questions wrong in the "Rotational Motion" section, or if you're a Physics 2 student, maybe "Magnetic Forces and Electromagnetism" is the bane of your existence. This is the time to become an expert! Open your class textbook to this section and spend about an hour going through the section, taking diligent notes. Try and work through about 15 questions pertaining to this topic at the end of the chapter, or seek questions out in a review book.

Make a note of why you got some questions wrong and make flashcards for each concept relating to the questions you got wrong.

Take a deep breath and do some stretches! You've already got 5 days done!

**Day 6**

**Physics 1 & 2**

*BIG REVIEW DAY ALERT! You can split this into 2 days if you have time or use tomorrow as a break instead.*

Don't give up now; it's time for flashcards again. Are you still taking notes for ones you are getting wrong? Good.

Go to **Albert.io** and do 10 questions randomly. Give yourself no more than 2 minutes to finish each question.

Now is the time to identify one more section that you find challenging. For example, if yesterday you chose "Rotational Motion", then maybe you also find "Electric Circuits" to be a pain.

# One Month AP Physics 1 & 2 Study Guide Cont.

If you're a Physics 2 student, maybe the next challenging topic is "Atomic and Nuclear Physics". This is the time to master another topic that has been causing you issues! Open your textbook to this section and spend about an hour going through the section, taking diligent notes. Try and work through about 15 questions pertaining to this topic at the end of the chapter, or seek questions out in a review book.

Make a note of why you got some questions wrong and make flashcards for each concept relating to the questions you got wrong.

Now, for the cherry on top! Have a friend or family member get all the flashcards together for the two sections that used to give you goosebumps and make them randomly select cards for you to answer. They need to be strict! Let them grill you! Hopefully this review will be a confidence builder. Previously difficult topics should be a bit more manageable now.

Run through 20 of your flashcards from your multiple-choice questions.
Give yourself a pat on the back for getting through the first week. You should be a bit more aware of the topical content of the exam now. Get some sleep, stay healthy, and report back for study duty next week! Dismissed!

**Start your AP Physics Prep today**

# One Month AP Physics 1 & 2 Study Guide Cont.

## WEEK 2

The purpose of this week is to get you to:

1. Go more in-depth and synthesize the "Big Ideas" of AP Physics 1 & 2

2. Do some practice problems

**Day 1**

We have a great week planned out for you and you're doing a fantastic job so far! Keep it up!

**Physics 1**

Go to **Albert.io** and do 10 questions randomly. Give yourself no more than 1 minute, 55 seconds to finish each question.

We are going to look at **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book**. You have to know that every question in the AP Physics 1 & 2 exam is based on three things: the 7 "Big Ideas", "Enduring Understanding" and "Essential Knowledge". For the first three days of this week, we are going to focus on building your essential knowledge, so when you approach a problem, your solution will come directly from the design of the course. Go to "Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure" (Page 125). Write down the pieces of "Essential Knowledge" (9 for Big Idea 1) on one side of 9 flashcards. On the other side, you are to *extend* this idea using information from your textbook, teacher, or online. For example,

| | |
|---|---|
| **"The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge"** | **1.) Keywords: electron charge = elementary charge**<br><br>**2.) e = 1.602E-19C 3.) First measured by Robert Millikan's oil drop experiment** |

# One Month AP Physics 1 & 2 Study Guide Cont.

Repeat this process for "Big Idea 2: Fields existing in space can be used to explain interactions"

**Physics 2**

Go to **Albert.io** and choose 10 questions to do randomly. No more than 1 minute, 55 seconds per question.

We are going to have a look at **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book**. Every question in both AP Physics 1 & 2 comes from three test design criteria: the 7 "Big Ideas", "Enduring Understanding" and "Essential Knowledge". For the next three days, we want to build up your essential knowledge. In other words, we will be "reverse engineering" each question. Go to "Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure" (Page 132). Write down the "Essential Knowledge" (17 for Big Idea 1) on one side of 17 flashcards. On the other side, you are to *extend* this idea using information from your textbook, teacher, online, or any other reliable resource. For example,

| | |
|---|---|
| **"Objects classically thought of as particles can exhibit properties of waves."** | **1.) A key concept of quantum mechanics and the effects are notable for elementary particles.**<br><br>**2.) DeBroglie equations: wavelength = h/p, where h is the Planck constant and p is the particle's momentum frequency = E/h, where E is the particle's energy**<br><br>**3.) Shown in experiments like matter wave diffraction of electrons** |

Do this again for all the sections of "Big Idea 2: Fields existing in space can be used to explain interactions"

# One Month AP Physics 1 & 2 Study Guide Cont.

**Day 2**

**Physics 1 & 2**

Go through the flashcards you made yesterday and quiz yourself.

We are going to look at **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** again. Write down the pieces of "Essential Knowledge" for Big Ideas 3 & 4 on one side of your flashcards. On the other side, you are to *extend* this idea using information from your textbook, teacher, or online as you did yesterday.

**Day 3**

**Physics 1 & 2**

Go through the flashcards you made the last two days and quiz yourself again.

We are going to look at **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** again. Write down the pieces of "Essential Knowledge" for Big Ideas 5, 6, & 7 (I know it's a lot) on one side of your flashcards. On the other side, you are to *extend* this idea using information from your textbook, teacher, or online as you did previously.

If you've done all the tasks this week, wonderful! If not, don't worry, you can continue tomorrow and finish them off. This section was pretty important because it taught you exactly the concepts that you will be expected to know on the test. See you tomorrow! Day 4

# One Month AP Physics 1 & 2
# Study Guide Cont.

**Physics 1 & 2**

You know the drill; go through the flashcards you made the last three days and quiz yourself.

Go to **Albert.io** and do another 10 questions randomly. Give yourself no more than 1 minute, 55 seconds to finish each question.

Now is the time to try and put this "Essential Knowledge" to the test. You are going to do some of the problems in the **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** and see how the "Essential Knowledge" relates to each problem. Go ahead and do 9 of the problems from the multiple-choice section (Pgs. 155-163 for Physics 1; Pgs. 189-196 for Physics 2) by only looking at the problems, do not look at the boxes below the problems yet.

Note: Recall that the multiple-choice section is 90 minutes long for 50 problems. That means you have 1 minute and 48 seconds for each question, meaning slightly over 16 minutes for 9 questions. Let's try and do it faster, so you'll practice having extra time to check answers when you take the test. Set a timer for 16 minutes and do not exceed this time!

Score yourself honestly. Look at the problems you got incorrect and find the flashcard that has the "Essential Knowledge" that indicates where you went wrong. If you need to add something to the card, do it at this time.

**Day 5**

Success! You're just about halfway through the review!

**Physics 1 & 2**

Go through all the "Essential Knowledge" flashcards and quiz yourself.

# One Month AP Physics 1 & 2
# Study Guide Cont.

Go to **Albert.io** and do 10 questions randomly. Give yourself no more than 1 minute, 55 seconds to finish each question. Make sure you stick to that and don't give yourself extra time.

We are visiting **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** again. Do problems 10-21 in the multiple-choice section. Give yourself 19 minutes this time! Score yourself and find the "Essential Knowledge" that corresponds to the question. See where you went wrong and add to the flashcard if necessary.

**Day 6**

**Physics 1 & 2**

*BIG REVIEW DAY ALERT!*

Don't give up now. Go through all the "Essential Knowledge" flashcards and quiz yourself once more.

We are going to go to **Albert.io** and do 15 questions randomly. Give yourself no more than 1 minute, 55 seconds to finish each question.

We are visiting **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** again. Do problems 22-25 in the multiple-choice section. Give yourself 7 minutes this time! Remember, these ones are quite special. They require you to select two answers that are correct. Score yourself and find the "Essential Knowledge" that corresponds to the question. See where you went wrong and add to the flashcard if necessary.

Run through 20 of your flashcards from your multiple-choice questions. Congratulations! We have made it through week 2! Keep up the good work.

**Start your AP Physics Prep today**

# One Month AP Physics 1 & 2 Study Guide Cont.

## WEEK 3

You're already in the second half! I know lots of ideas and concepts are swimming about in your head, but let's keep going. The good thing is, setting a more long-term study plan like this one will allow you to organize the concepts better in your head. Cramming doesn't work well for trying to remember this much information. The purpose of this week is to get you to:

1. Get you ready for the free-response and experiment section of the exam

2. Get you acquainted with more study resources

**Day 1**

**Physics 1 & 2**

Let's start by going to **Albert.io** and you will do 10 questions randomly. Give yourself no more than 1 minute, 50 seconds to finish each question.

Now it's time to do some free-response questions. This section, only consisting of 4 questions, is deceptively simple. Fifty minutes for 4 questions? What a piece of cake! Maybe this section seems simple, but as you'll see, it's actually one of the main sections that will make or break your score of 4 or 5. You really need to get a feel for how these questions are evaluated, so that's one of our main goals for this week. **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** only has 3 practice free-response questions for each Physics 1 & 2. According to the booklet: "Question 1 is a short free-response question that requires about 12 minutes to answer (Physics 1) or 15-20 minutes (Physics 2) to answer and is worth 10 points. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each." Today you're going to set aside 37 minutes for Physics 1 and 42 minutes for Physics 2 for the completion of Questions 1 and 2 (Pages. 177-179 for Physics 1; Pages. 211-213 for Physics 2). Set a timer. Do not look at the boxes below the problems, just focus on writing the problem.

# One Month AP Physics 1 & 2
# Study Guide Cont.

When the 42 minutes is up, stop and go evaluate the problems which you have completed, honestly and ruthlessly. I know it's a little difficult to evaluate given the instructions, but go point by point and add them up.

Find the "Essential Knowledge" that you may have missed on the problems where points were subtracted. Add information or tidbits if necessary.

Rewrite your response, given the rubric, so that you would have scored 100% on the problem. Note where you deviated from the "perfect" score and how you can organize your explanation or experiment design better.

**Day 2**

**Physics 1 & 2**

Start with **Albert.io** and do 10 questions randomly. Once again, time yourself and give yourself no more than 1 minute, 50 seconds to finish each question.

We're doing **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** again. Today you're going to set aside 25 minutes for the completion of Question 3 (Pgs. 180-181 for Physics 1; Pgs. 215-216 for Physics 2). Set a timer. Do not look at the boxes below the problems, just focus on writing the problem for now.

When the 25 minutes is up, stop and go evaluate the problems and be honest in your grading.

Find the "Essential Knowledge" that you may have missed on the problems where points were subtracted. Add information or tidbits if necessary.

Rewrite your response, given the rubric, so that you would have scored 100% on the problem. Note where you deviated from the "perfect" score and how you can organize your explanation or experiment design better.

# One Month AP Physics 1 & 2
# Study Guide Cont.

Run through 20 of your flashcards from your multiple-choice questions.

**Day 3**

**Physics 1 & 2**

We are almost halfway through another week! Don't give up now!

Go to **Albert.io** and do 10 questions randomly. Give yourself no more than 1 minute, 50 seconds to finish each question.

This week is all about free-response questions. Visit the **AP Central Free Response Questions** and go to Physics 1 or Physics 2 under the STEM heading. Near the bottom of the page, you will see the 2015 Free-Response Questions. Click on it and you will do one full, 50-minute free-response section.

Evaluate your free-response section honestly. For each question, write a "perfect score" example and compare it to your own answer. Don't worry if your scores are not perfect now, you'll get closer and closer to perfection the more you practice!

**Day 4**

**Physics 1 & 2**

You know the drill; go to **Albert.io** and do 10 questions randomly. Don't forget to time yourself for each question.

Go back to **AP Central Free Response Questions** and go to Physics 1 or Physics 2 under the STEM heading. Near the bottom of the page, you will see a link for past AP Physics A/B Exams. Click on it and you will do one full, 50-minute free-response section from a recent year.

Evaluate your free-response section honestly. For each question, write a "perfect score" example and compare it to your own answer.

# One Month AP Physics 1 & 2 Study Guide Cont.

Make sure you note the discrepancies between the first and second answer so you can see how to improve your answer for the next time.

**Day 5**

**Physics 1 & 2**

Let's do another 10 questions on **Albert.io** today.

Return again to **AP Central Free Response Questions** and go to Physics 1 or Physics 2 under the STEM heading. You will do another full 50-minute free response question today. After you evaluate your score you can have another person (a friend or family member) read it as well. Don't forget to write a perfect answer and compare the two answers.

The weekend is finally here and you're still going strong! Way to go! Day 6

**Physics 1 & 2**

*BIG REVIEW DAY ALERT!*

Go to **Albert.io** and do 10 questions from the section you identified in the first week as the hardest for you, and 10 questions from the section that was the second hardest for you. Make sure you time yourself; 1 minute and 50 seconds to finish each question.

If you did well, then congratulations are in order. If you didn't do as well as you wanted, then it's time to hit the books again. Pull out your textbook. Compile flashcards from the summary notes at the end of each chapter. Remember, a useful flashcard is not just a formula. Like above, good flashcards tie together concepts, definitions, formulas, handy information, and visual cues.

Stand up out of your seat and do some stretches to get the blood flowing!

# One Month AP Physics 1 & 2 Study Guide Cont.

Return once again to **AP Central Free Response Questions** and go to Physics 1 or Physics 2 under the STEM heading. Near the bottom of the page, you will see a link for past AP Physics A/B Exams. Click on it and you will do one full, 50-minute free-response section from another recent year. This database of free-response questions is yours to use how you want. If you find the free-response section to be weaker for you than the multiple-choice section, you might want to replace some study time in week 4 that is designated for multiple-choice time for free-response time instead.

Evaluate your free-response section honestly. You can ask someone else to help you grade it once more. Having a fresh set of eyes can help you catch mistakes you might not have seen. For each question, write a "perfect score" example and compare it to your own answer.

Get a glass of water or something good to drink and pat yourself on the back for being so dedicated to studying. You've earned it.

Grab a friend/family member and have them sit down with you to review 50 flashcards. Having people to help you such as friends or a family member will make the experience much less taxing mentally and they can offer you support.

Optional, but highly recommended for Sunday (Sorry, but there goes your precious weekend!): Since you have more time on the weekend, it's about time to go through an entire test (yes, all 3 hours of it, no distractions). A good resource for full-length practice tests is the 5 Steps to a 5 AP **Physics 1** & **Physics 2** 2016 Ed. as referred to in the optional materials section. Set aside about four hours for taking the test, evaluating, and compiling the necessary flashcards. If you don't have or can't get this book, ask your teacher or seek online resources. Online resources, however, aren't necessarily updated. Remember, AP Physics A/B materials aren't useless, but the test was updated, so use them wisely. The newer the resource, the better, as a rule of thumb.

**Start your AP Physics Prep today**

# One Month AP Physics 1 & 2 Study Guide Cont.

**WEEK 4**

The purpose of this week is to get you to:

1. Get many questions under your belt

2. Understand how to connect concepts with test questions

Are you staying healthy? Are you sleeping well? Are resistors and capacitors in parallel and series drifting in and out of your dreams? The four best ways to stay healthy when you're working hard are:

1. Get some proper shut-eye (7-9 hours per the Surgeon General's recommendation)

2. Eat well (don't binge on snack food)

3. Drink plenty of water (hopefully the bathroom is nearby)

4. Exercise regularly (this might be a good way of getting breaks between studying anyway)

You're almost there, the finish line is within sight. Stick with it! It's tough, but you're already ahead of the game because you're on here studying!

**Day 1**

**Physics 1**

Once again, go to **Albert.io** and do 20 questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question. You've had a good amount of practice with the questions by now, so we're decreasing the time allowed for each question.

# One Month AP Physics 1 & 2 Study Guide Cont.

You have seen many problems by this point and you have made many flashcards too. Without getting too lost in the confusion of quantity, let's focus again on the "Essential Knowledge" that you spent time on during Week 2. This is a notebook task. Ideally, you have an empty notebook or a clean section of a notebook (or a document on your computer) on which you can do the following task. Pick 10 problems you found particularly difficult and find the "Essential Knowledge" for it. You are going to write the "Essential Knowledge" down on the top of the page, with the information on the back of the flashcard next to it. Then you are going to write the problem down under the heading "Example Problems". Find one more problem that addresses the same "Essential Knowledge". For example:

| | |
|---|---|
| Essential Knowledge: "Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system." | The electron is also known as the elementary charge (nothing has charge smaller, i.e. we count charge in units of $e$) Charge of an electron: $e$ = 1.602E-19 C Just like conservation of mass/energy |

**Example Problems:**

1) In an experiment, three microscopic latex sphere are sprayed into a chamber and become charged with $+3e$, $+5e$, and $-3e$, respectively. Later, all three spheres collide simultaneously and then separate. Which of the following are possible values for the final charges on the spheres?

Answer: Three charges must add up to $+5e$ as a system and there cannot be a fraction of a charge, because $e$ is the elementary charge.

2) Sphere A and Sphere B are metal spheres of identical size and shape. They are set on insulating stands, and each has a different net charge. Spheres A and B come into contact. A spark between the spheres indicates that a charge is transferred. After contact, each sphere has a charge of negative 5 micro-coulombs. If the charge on Sphere A was positive 22 micro-coulombs before contact, what was the charge on Sphere B before contact?

Answer: The sum of the charges before contact and after contact for the whole system consisting of two spheres must be equal.

Find a related problem from your textbook and do it. Then take some deep breaths and do some stretches, maybe even walk around the block once or twice.

**Physics 2**

Go to **Albert.io** and find 20 questions to do randomly. No more than 1 minute, 45 seconds per question.

By this point, you will have already gone through quite a few problems, and have compiled quite a stack of flashcards, in fact, quite a bit more than Physics 1. Let's return again to the "Essential Knowledge" that you took notes on during Week 2 as these concepts are central to the test design. Go to **CollegeBoard's Official AP Physics 1 & 2 Course and Exam Information Book** and bring out your notebook. Hopefully, you have a blank notebook or, at least, a blank section (or you are welcome to create a document on your computer) on which you can do the following task. Think back on the problems you have gone over. Hopefully, the thorny problems that gave you trouble are still in the back of your mind. Choose 10 of them and find the "Essential Knowledge" for each. You are going to write the "Essential Knowledge" corresponding to each 10 questions at the top of a blank page with the information on the back of the flashcard next to it. Then you are going to write the problem that caused you so much pain down under the heading "Example Problems" below. Search your memory for another problem that addresses the same "Essential Knowledge" and write it down too. For example:

| | |
|---|---|
| **Essential Knowledge: "Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge."** | **Like charges repel, and opposite charges attract The electric force is proportional to 1/r^2, where r is the distance between the charges. The electric force is proportional to the charges.** |

**Example Problems:**

**1) Three charges of equal magnitude are placed at [three distinct] corners of a square of side length L. In what direction is the net electric force acting on the middle charge?**

**Answer: Both the charges in the other corners repel the middle charge. So, the middle charge will be pushed diagonally outside the box.**

**2) There are two charges, q1 = -3.0 micro-coulombs and q2 = -8.0 micro-coulombs. In which general region could a third charge q3 = +5.0 micro-coulombs be placed so the net force on q3 would be zero?**

**Answer: The force from q2 is stronger than q1 at the same r. They are both attractive forces. Therefore, the charge q3 should be placed closer to q3 on the line between q1 and q2.**

# One Month AP Physics 1 & 2 Study Guide Cont.

Now, turn to your textbook and do a problem that relates to the same "Essential Knowledge". Then, try and relax for a few minutes before moving on from this to something else. Your body and mind need breaks.

**Day 2**

**Physics 1**

Go to **Albert.io** and do 20 questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question.

Review (briefly) from your textbook, making flashcards for key concepts. As you go through the topics below, you are going to visit Youtube and find a relevant video(s). Go to either **Flipping Physics** and/or **Dan Fullerton** for Physics 1 or **Yau-Jong Twu** for Physics 1 & 2 or perhaps another channel if you prefer that.

- Kinematics
- Dynamics: Newton's laws
- Circular motion and universal law of gravitation

DANGER!!! WARNING!!! Stay focused on the Youtube channel, and do not go astray! If you find yourself watching music videos, then maybe using Youtube to study is not helpful.

**Physics 2**

Go to **Albert.io** and choose 20 questions to do randomly. No more than 1 minute, 45 seconds for each question.

Review (briefly) from your textbook the topics below, while making flashcards for each concept you think is important. As you peruse your textbook, you are going to go to Youtube and find a video(s) that addresses the same topic.

# One Month AP Physics 1 & 2 Study Guide Cont.

Go to **Yau-Jong Twu** for Physics 2 or perhaps another channel if you prefer that.

- Thermodynamics: laws of thermodynamics, ideal gases, and kinetic theory
- Fluid statics and dynamics

DANGER!!! WARNING!!! Stay focused on the Youtube channel, and do not go astray! If you find yourself watching funny videos, then maybe using Youtube to study is not helpful.

**Day 3**

**Physics 1**

Go to **Albert.io** and do 20 questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question.

One again, review (briefly) the topics listed below. As you go through each topic, you are going to visit Youtube and find a relevant video(s). Go to either **Flipping Physics** and/or **Dan Fullerton** for Physics 1 or **Yau-Jong Twu** for Physics 1 & 2 or perhaps another channel if you prefer that.

- Simple harmonic motion: simple pendulum and mass-spring systems
- Impulse, linear momentum, and conservation of linear momentum: collisions
- Work, energy, and conservation of energy
- Rotational motion: torque, rotational kinematics and energy, rotational dynamics, and conservation of angular momentum

# One Month AP Physics 1 & 2 Study Guide Cont.

**Physics 2**

Go to **Albert.io** and do 20 questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question.

Review (briefly) the topics listed below.  As you go through each topic, you are going to visit Youtube and find a relevant video(s). Go to **Yau-Jong Twu** for

Physics 2 or perhaps another channel if you find a good one.

- Electrostatics: electric force, electric field and electric potential
- DC circuits and RC circuits (steady-state only)
- Magnetism and electromagnetic induction

**Day 4**

**Physics 1**

You're so close to the finish line, don't stop now!

Go to **Albert.io** and do another 20 questions.  Give yourself no more than 1 minute, 45 seconds to finish each question.

Today you will review the topics below and you can supplement with your favorite youtube channel.

- Electrostatics: electric charge and electric force
- DC circuits: resistors only
- Mechanical waves and sound

# One Month AP Physics 1 & 2
# Study Guide Cont.

**Physics 2**

Go to **[Albert.io]** and do 20 questions.  At this point, you should have tackled a lot of them already. Give yourself no more than 1 minute, 45 seconds to finish each question.

Review (briefly) the concepts below and supplement with a youtube video if you need it.

- Geometric and physical optics
- Quantum physics, atomic, and nuclear physics

**Day 5**

You're almost there! We applaud you for your devotion!
Physics 1 & 2

Go to **Albert.io** and do 20 questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question.

Grab a friend/family member and have them sit down with you to review 60 flashcards.

Visit **http://apcentral.collegeboard.com/apc/public/exam/examinformation/index.html** again and go to Physics 1 or Physics 2 under the STEM heading. Near the bottom of the page, you will see a link for past AP Physics A/B Exams. Click on it and you will do one full, 50 minute free-response section from another recent year.

# One Month AP Physics 1 & 2
# Study Guide Cont.

**<u>Day 6</u>**

**Physics 1 & 2**

Here it is, the last day. If you've stuck with us until this point, then you certainly have the right attitude to get a 5 on the test. *BIG REVIEW DAY ALERT!*

Go to **Albert.io** and do the remainder of the questions randomly. Give yourself no more than 1 minute, 45 seconds to finish each question.

Sit down and review your "Essential Knowledge" flashcards. As you review them, this time try and visualize problems that you have encountered (or not) that relate to these concepts.

It would be amiss on this study review to not recommend that you <u>must</u> complete one full-length exam prior to taking the real one. So, without further ado (just like last week if you did it):

A good resource for full-length practice tests is the 5 Steps to a 5 AP **Physics 1** & **Physics 2** 2016 Ed. as referred to in the optional materials section. Set aside about four hours for taking the test, evaluating, and compiling the necessary flashcards. If you don't have or can't get this book, ask your teacher or seek online resources. Online resources, however, aren't necessarily updated because the test has changed. Remember, AP Physics A/B materials aren't useless, but they may be misleading, so use them wisely. Make sure to take the exam under test conditions. Once you are done, grade yourself and review your flashcards is something is still not clicking.  You can review your flashcards for the next few days but don't try to cram too much before the exam. We can't stress that enough.

Hopefully, this one-month study guide has gotten you ready for the AP Physics 1 and/or 2 exam. You're hard work will pay off! Committing to and completing this study guide already shows your dedication and seriousness for this AP test. Best of luck to you!

# One Month AP Physics 1 & 2
# Study Guide Cont.

***Let us know*** *what has worked for you. What did you like best about this one month study guide? Do you have recommendations of your own on how to study for the AP Physics exam?*

**Start your AP Physics Prep today**

# The Ultimate List of AP Physics 1 & 2 Tips


In order for you to score a 4 or 5 on the AP Physics exam (1 or 2), it is important for you to follow the tips outlined below. In 2015, only 22.4% of students who took the AP Physics 2 exam received a grade of 4 or 5. The AP Physics 1 & 2 exams cover all of the topics in the previous AP Physics B & C exams plus some additional ones as well. Take the time to review the following tips which cover both the AP Physics 1 & 2 exams, and you'll be well on your way to earning the highest possible score on your AP Physics exam. Relax, read and absorb the tips as you go! Good luck!

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

## How to Study for AP Physics Exam Tips

**1. Know the specific topics covered on the exam:** The AP Physics exam will cover a number of specific concepts including Newtonian dynamics, circular motion, universal gravitation and much more. See the following table for a comprehensive list of topics and concepts covered in the AP Physics exam:

| AP Physics 1 | AP Physics 2 |
|---|---|
| **Kinematics** | **Thermodynamics: laws of thermodynamics, ideal gases, and kinetic theory** |
| **Dynamics: Newton's laws** | **Fluid statics and dynamics** |
| **Circular motion and universal law of gravitation** | **Electrostatics: electric force, electric field and electric potential** |
| **Simple harmonic motion: simple pendulum and mass-spring systems** | **DC circuits and RC circuits (steady-state only)** |
| **Impulse, linear momentum, and conservation of linear momentum: collisions** | **Magnetism and electromagnetic induction** |
| **Work, energy, and conservation of energy** | **Geometric and physical optics** |
| **Rotational motion: torque, rotational kinematics and energy, rotational dynamics, and conservation of angular momentum** | **Quantum physics, atomic, and nuclear physics** |
| **Electrostatics: electric charge and electric force** | |
| **DC circuits: resistors only** | |
| **Mechanical waves and sound** | |

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

The two separate AP Physics exams are called **AP Physics 1: Algebra-Based** and **AP Physics 2: Algebra-Based Curriculum Framework**. Start reviewing and memorize the standard equations of rectilinear motion shown below:

$$v = v_0 + at$$

$$r = r0 + v0t + \frac{at^2}{2}$$

$$r = r0 + (\frac{v+v0}{2})t$$

$$v^2 = v0^2 + 2a\,(r - r0)$$

$$r = r_0 + vt - \frac{gt^2}{2}$$

You will need these equations for all problems related to objects in motion. Review the concepts of distance, velocity and acceleration and know how to use and apply them to a specific problem. Often times you will be given an initial distance, velocity or acceleration or any combination thereof. Take ALL the information that is given and place it on your worksheet. Assign values to all of the given variables and then decide which equation would be most appropriate to use.

**Here are some examples of the types of rectilinear motion problems you will encounter:**

- Finding final velocity given initial velocity and constant acceleration
- Finding final distance given initial distance, velocity and acceleration
- Finding acceleration given initial velocity, distance and time
- Finding the velocity of an object in free fall (acceleration = -g)
- Finding the distance of a projectile given an initial velocity and angle
- Finding the instantaneous velocity or acceleration of a rotating object

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**2. Visit Georgia State University's Hyperphysics website:** We strongly recommend going to the [Hyperphysics website] for tons of basic concepts and highly detailed illustrative diagrams. You will navigate intuitively throughout the website and study whichever physics topic your mind desires. The website employs concept maps and other linking strategies to facilitate easy and smooth navigation. If you are having difficulty in understanding a particular concept in physics, it would be a great idea to visit this site.

**3. Search the Internet for physics problems:** Drawing from the topics outlined in the table in Tip 1, conduct the following searches using these keywords: AP Physics problems, sample kinematics problems, circular motion problems, etc. If you find a site that is relevant, bookmark it and go onto the next topic. Once you have a few websites bookmarked, start doing some sample problems. Also, some sites will have questions that are already answered and will walk you through the various steps of the problem. This is an excellent way to improve your skills in preparation for the AP Physics exam.

**4. Buy one or two recommended physics textbooks:** Check out a number of excellent textbooks listed on this **website**. Make sure that the ones you choose cover the fields of physics you need the most help in. Most of the books will cover just about all of the topics covered on the AP Physics exam. When you get them, read them carefully and do the problems listed at the end of each chapter to test your ability and competency. This will give you a good taste of what is to come when you actually take the exam.

**5. Get a good calculator that has all of the common constants:** We highly recommend the **Casio Fx-115 ES Plus**. It contains even more universal physical, thermodynamic and electromagnetic constants than you will need. It also contains a way to convert metric units into English and vice versa. Some of the constants you will need for the AP Physics exam are the following: Newton's gravitational constant, speed of light, permittivity of free space, masses of the electron, proton and neutron.

# The Ultimate List
# of AP Physics 1 & 2 Tips Cont.

**6. Understand and memorize the following basic equations:** Memorize only the basic equations that you will need for the exam. CollegeBoard has an excellent resource for this and it is broken down into all of the categories. You don't need to memorize all the equations but you should at least know the basic ones for Newtonian mechanics, electricity & magnetism, optics (especially Snell's Law as it relates to index of refraction), fluid mechanics, thermodynamic equations (i.e., specific heat), and atomic and nuclear physics. Here is a list of some of the basic equations you should know:

| | | |
|---|---|---|
| **Velocity**<br>$\vec{v} = \frac{\triangle s}{\triangle t} = \frac{ds}{dt}$ | **Acceleration**<br>$\vec{a} = \frac{\triangle \vec{v}}{\triangle t} = \frac{d\vec{v}}{dt}$ | **Newton's Second Law**<br>$\vec{F} = m\vec{a}$ |
| **Momentum**<br>$\vec{p} = m\vec{v}$ | **Centripetal Acceleration**<br>$\vec{a_c} = \frac{\vec{v}^2}{r}$ | **Impulse Momentum**<br>$\vec{F}\triangle t = m\triangle\vec{v}$ |
| **Kinetic Energy**<br>$E_k = \frac{mv^2}{2}$ | **Power**<br>$P = \frac{\Delta W}{\Delta t} = \frac{dW}{dt}$ | **Angular Velocity**<br>$\vec{\omega} = \frac{\triangle\theta}{\triangle t} = \frac{d\theta}{dt}$ |
| **Angular Acceleration**<br>$\vec{a} = \frac{\triangle\vec{\omega}}{\triangle t} = \frac{d\vec{\omega}}{dt}$ | | |

**7. Know the difference between a scalar and a vector quantity:** In physics both scalar and vector quantities are common. A scalar only has a magnitude and a vector has a magnitude and a direction. A vector description is considered incomplete if it does not have a direction specified. Also, realize that equations employing vector quantities contain unit vectors. These unit vectors have a magnitude of one and are pointed in the same direction as the resultant vector.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

The most common equations employing vector quantities are those of motion (position, velocity and acceleration), angular velocity and acceleration, torque, angular momentum, force equations including Young's modulus, universal gravitation and gravitational potential. For equations in electricity and magnetism employing vector quantities; these include Coulomb's Law, electric field and potential equations, electric and magnetic flux and motional and induced EMF.

**8. Understand individual concepts in all of the categories:** Become very familiar with all of the individual concepts of the topics listed in Tip 1. Pay attention to the units of measure for each variable and know how the variables are interrelated to each other and to the force in which they describe. Prepare a table of the basic forces and the units that are used to express those forces as a study guide. Alongside this table, create another table with the variables and their respective units for each force or property. This study guide is for your sole personal use when preparing for the AP Physics exam, but you will not be able to use it when taking the exam.

**Start your AP Physics 1 & 2 Prep today**

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**AP Physics Multiple-Choice Review Tips**

AP Physics is a three-hour exam broken into two sections, each section lasting ninety minutes long. Each section represents 50% of your total score. The multiple-choice section contains 50 multiple-choice questions and contains discrete items, items in sets and multi-select items (where two options are correct). The multi-select questions are arguably the most difficult of all the multiple-choice questions so make sure to allocate more time on these. Beginning in May 2015, each multiple-choice question only contains four answer options rather than five.

1. **Review the College Board AP Physics 1 & 2 course and exam description:** We highly recommend students prepare for the AP Physics exam by reviewing the College Board's course and exam description **here**. The document contains many essential knowledge concepts that will significantly enhance your ability to solve problems and bolster your overall understanding of physics.

**2. Practice common problems involving the force of friction:** In Newtonian mechanics, the force of friction or "inclined plane" problems is very common. Let's take a simplified example where there is no inclined plane. Suppose we have a box that has a mass of 25kg and it takes a force of 75N to move it, what is its static coefficient of friction? First we calculate the normal force $F_n$ (which is simply the weight of the box) using the equation $F_n = mg$ where g is the gravitational constant $9.8 m/sec^2$. $F_n = 245N$. Then, to find the static coefficient of friction μ we simply take the force needed to move the box and divide it by its weight to get $\mu = 0.306$. Since μ is the quotient of two forces of the same unit (Newtons), it is a unit-less number.

For inclined plane problems you must draw a detailed diagram showing the x and y components of the weight of the box as shown below:

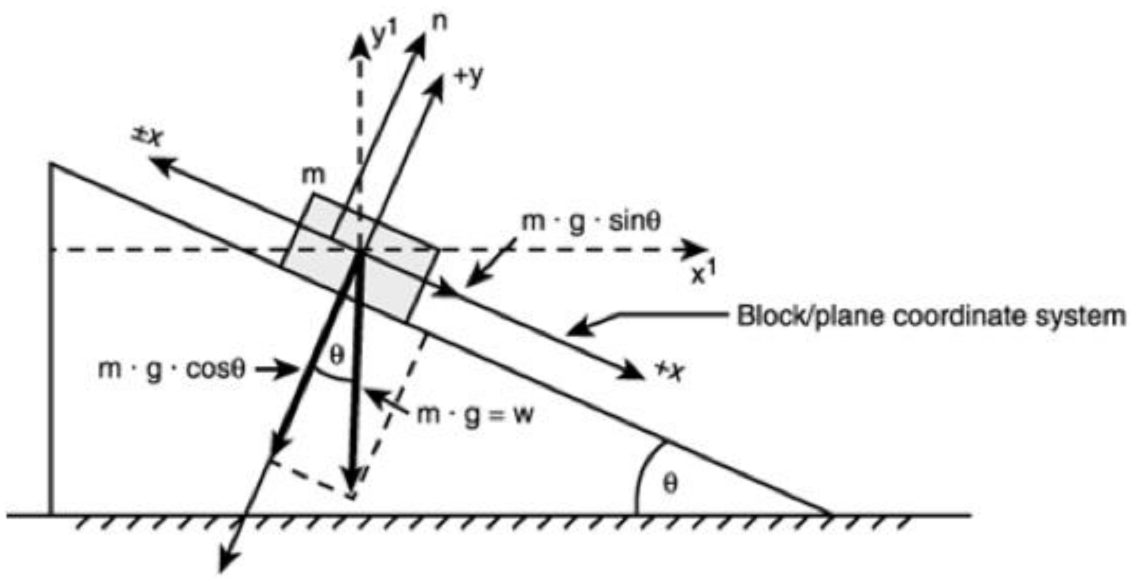



*Image Source: Yaldex.com*

**3. Know the common units of the major quantities in both the CGS and MKS systems:** Study the following table which gives some of the most common units used in physics in both metric systems:
Make sure that you are consistent with the units of either system when doing problems. If the problem starts out in MKS units make sure you solve the problem in those units. If you need to convert from one system to another, make sure you are doing it properly.

**4. Make diagrams for certain problems:** Many problems on AP Physics are best tackled drawing a small diagram. This is especially important if you are asked to calculate a force in a particular direction. Draw a coordinate axis and any vectors or component vectors on the diagram. Mark each vector with a symbol having a defining subscript. For example, the component force of acceleration in the x direction should be denoted as $a_x$.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**5. Dissect multi-select questions:** There will only be five multi-select questions on this part of the exam. Get a firm grasp of the question and then find the best two answers. Gather your thoughts and the crucial concepts of the question and read each answer carefully. If you find one that is obviously wrong, place a check mark or an “X” next to it. Use the process of elimination to the best of your ability. Draw a diagram or write down an equation that may be relevant to the question. With the equation written down it will be much easier for you to determine whether one variable is decreasing or increasing and what affect that will have on the variable pertaining to the question.

**6. Review important conservation relationships:** All quantities in dynamic physics are conserved. For example, in a collision between two objects, linear momentum is conserved. However, if the collision is inelastic, the kinetic energy (and also the momentum) before and after the collision are not the same although the **<u>total energy of the system is always conserved</u>**. In the inelastic case, some of the energy of the collision is taken away by internal friction and is dissipated as heat energy. The conservation of momentum relation applies to angular momentum as well (both on the macro and subatomic quantum levels). The conservation of momentum and energy are fundamental laws of physics. You will need to use them frequently when solving many problems in physics.

**7. Know and understand the relationship between work, energy and power:** Work refers to an activity involving a force in the same direction of the force (e.g., a force of 200 Newtons pushing an object 10 meters in the same direction of the force has performed 2,000 Joules of work). Energy refers to the “capacity of doing work”. In other words, you need a certain amount of energy to perform a certain amount of work. Using the previous example, we needed 2,000 Joules (2kJ) of energy to perform the task of pushing the object. Power is simply the rate of doing work, or the rate of using energy, and is the amount of work that is done during a certain amount of time $P = \frac{W}{\Delta t}$. In our example above, if it took us 2 seconds to move the object, the amount of power that was output was 1,000 Watts or 1kW.

# The Ultimate List
# of AP Physics 1 & 2 Tips Cont.

**8. Practice drawing vector diagrams and know how to add and subtract them:** Vector diagrams and vector algebra are at the very heart of physics. It is crucial to know how to add and subtract vectors graphically using the head-to-tail approach starting at the origin of a Cartesian coordinate axis and to draw the correct **resultant** vector. For vector addition it does not matter which vector you draw first since addition is commutative. For subtraction, however, make sure that the vector you draw first is the one you are subtracting from. The next step(s) are the same as addition. Place the tail of the second vector at the head of the first one. Continue doing this until you have all the vectors in place. Then simply draw a line from the origin to the head of the final vector. This line will be the resultant vector of the subtraction. See the example below:

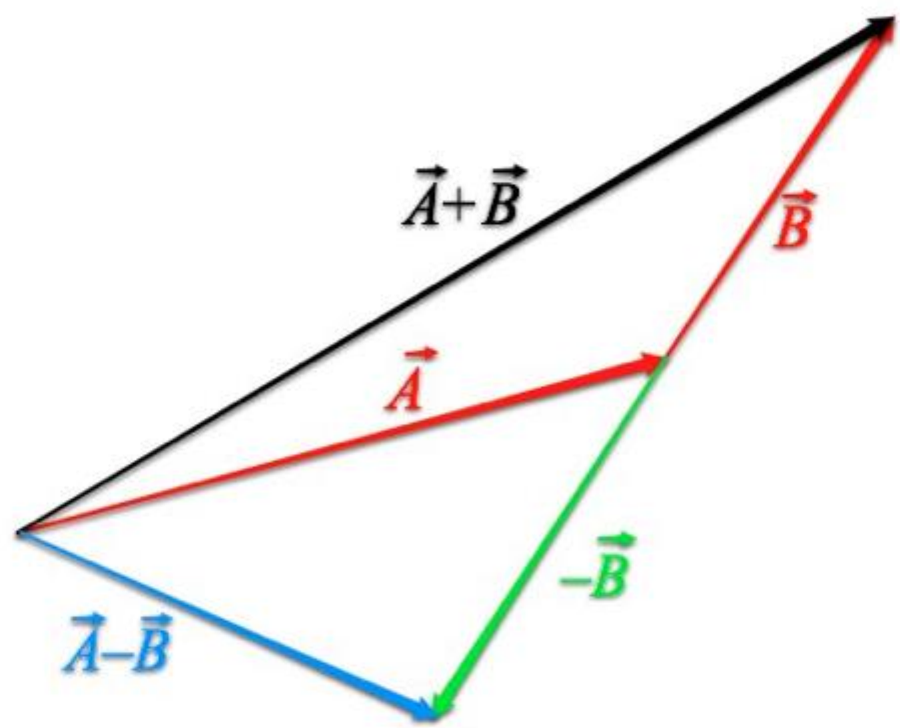



*Image Source: sph3u1-0.blogspot.com*

The above figure shows the resultant vector sum $\vec{A} + \vec{B}$ in black and the resultant vector subtraction $\vec{A} - \vec{B}$ in blue.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

Below is another figure illustrating the subtraction of two vectors. Notice that the negative value of a vector points 180$^{\circ}$ away (parallel and opposite) from its positive counterpart:

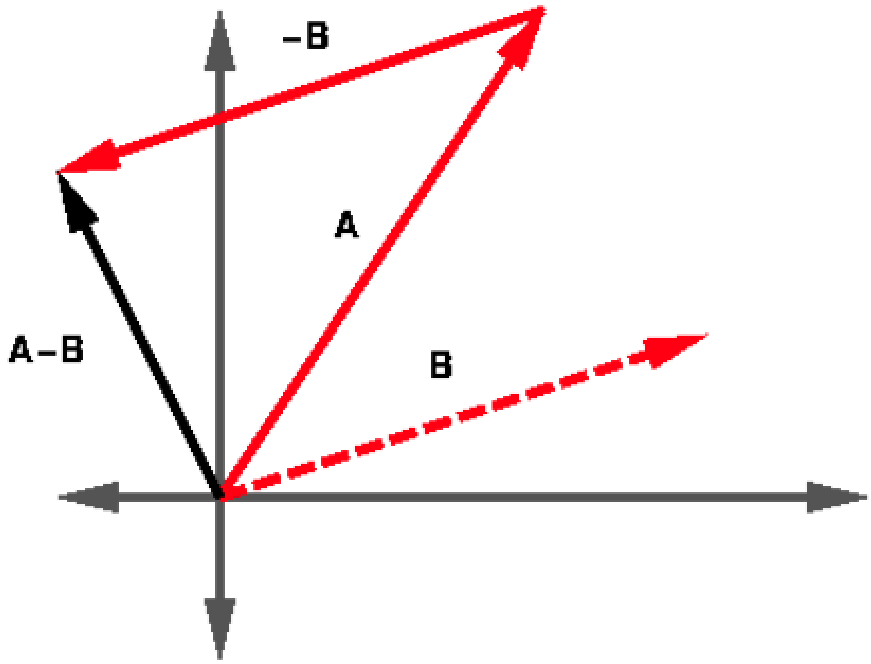



*Image Source: webphysics.iupui.edu*

**9. Use Kirchoff's Loop Law for electric circuits:** The AP Physics 1 exam introduces simple electrical circuits employing only resistors whereas the AP Physics 2 exam includes circuits containing RC components. The student needs to understand Ohm's Law (E = IR) and the conservation of electrical charge (voltage energy) and currents in closed electrical DC circuits. Kirchoff's Law is broken up into two parts: Kirchoff's Current Law (KCL) and Kirchoff's Voltage Law (KVL). For a more in depth discussion regarding Kirchoff's Laws, visit this **Wikipedia site**.

**Start your AP Physics 1 & 2 Prep today**

# The Ultimate List
# of AP Physics 1 & 2 Tips Cont.

## AP Physics Free Response Question Review Tips

There are five Free Response Questions (FRQs) on the AP Physics 1 exam. There is one based on experimental design, another related to quantitative and qualitative translation and another three that are short answers. The AP Physics 2 exam follows the same format except that there are only two short answer type questions. In scoring the FRQs, credit for the answers depends on the quality of the solutions and the explanations given. Partial solutions may receive partial credit so it is important to show all your work. A table of information and equations needed for the exam are available for students at least one year before the exam. You will be given the exact same information (values of physical constants, etc.) and equations when you take the exam. You cannot bring your own copy to the exam. See the Appendix on page 225: AP Physics 1 and 2 equations and constants **here** for the most recent copy (2015).

**1. Use paragraph length responses:** Some FRQs on the AP Physics exam will require you to provide a coherent, organized and sequential description of the situation presented. If so, provide an accurate, concise and factually based response to the question in the form of a paragraph utilizing prose. Make sure that you do not add any erroneous information or subject matter. Read the question carefully and focus on answering all parts of the question in the order that they appear.

**2. Cite physical principles and equations:** Style your exposition in a simple manner to describe and/or explain in a short paragraph what the question is asking for. Also, only use the appropriate equations and principles needed to answer the question. Focus only on answering the question and avoid any digression(s). You will lose credit if you only write down a bunch of equations without any written explanation. Use diagrams, equations, graphs and calculations to support your line of reasoning. Keep your paragraph(s) short to moderate in length and make sure that they make sense on the first reading.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**3. Describe and explain questions:** Utilize your skills in writing and in depth knowledge of physical principles to answer these types of questions. Justify your answers by using an argument which is supported by key evidence. The evidence should include the fundamental law(s) of physics, diagrams, graphs, equations, calculations and data.

**4. Draw a free-body diagram for mechanics and motion problems:** Draw a free-body diagram for questions involving inclined plane problems, motion problems, pulley problems and any other problems having a number of vector components. In this manner, you will be able to better visualize all of the forces at a glance. Clearly indicate all the forces and their components. Use appropriate units for the numerical values of any physical quantities. Leaving out units, and directions in the case of vectors, will cost you points!

**5. Skim all the problems prior to solving:** Take a minute or two to quickly skim the FRQs to get an assessment or indication of which question looks easier to answer. You will likely see one or two that you feel more comfortable with so you should start on those problems first. Gauge your time to about 15 minutes for each problem.

**6. Practice as many previous FRQs as possible:** Two to three months before you take the AP Physics exam, review past FRQs. The College Board website will have some **examples** you can study. However, don't rely on just a few samples. **Here** is an excellent website containing dozens of sample exams from previous years in addition to the chapter problems for the Giancoli physics textbook and the course work from the Massachusetts Institute of Technology.

**7. Form a study group of your peers:** Schedule a time and place where you can get together with classmates to discuss and solve physics problems. It doesn't need to be a formal or weekly thing but at least communicate with them and try to meet each other from time to time. Ask them if they would be open to you calling them whenever you are having difficulty with a particular problem. You may be able to help them and they may be able to help you.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**8. Underline all interim solutions:** If an FRQ asks you to calculate a certain quantity which involves several steps (and most will), underline numerical values that you will be using in subsequent calculations. If you are asked to derive an equation from basic principles, make sure that you underline **OR** better yet, number the equations in each step of the derivation. This way you can refer to each numbered step when providing your written paragraph explaining or justifying your final answer.

**9. Indicate all relevant equations, steps and principles (Laws):** When answering any FRQ, it is important to show all of the equations, interim answers with the correct values and units. Since the answer to an FRQ is in a paragraph format, make sure that you indicate any core principles or key Laws of Physics that you used in order to solve or to explain the problem. We recommend drawing a box around any key interim equations or answers.

**10. Use prose for paragraph responses:** The style of your paragraph is important for both the AP Physics 1 & 2 exams. You must present the principles used for each FRQ in a logical manner. If the principles are out of order and you use lengthy and meaningless arguments or explanations, you will lose points. You need to write the paragraph in exposition form using prose so as to guide the reader logically and clearly to the correct answer. Use correct prose so that the sentences flow naturally. Be succinct but to the point. Do not add any irrelevant information as this will cause you to digress from the subject matter and lose points.

## Tips by AP Physics Teachers

**1. Study each topic individually:** Spend time studying each topic individually and one by one. Don't skip all over the place and study just one part of Newtonian mechanics and then jump to electrostatics. Focus your energy on a single topic until you master it completely before going onto the next topic. For example, know and completely understand how to use the equations of rectilinear motion before going to harmonic motion or work-energy problems. It is always best to master one topic before proceeding to the next.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**2. Use a logical progression of steps when going through the topics:** This tip is related to the previous tip. Use the table at the very beginning of this article as a guide or road map to determine the order in which to study. Master the equations and concepts of kinematics first and then proceed to Newton's Laws of Dynamics. Then proceed to the more advanced topic of circular motion which has similar concepts to kinematics except that it is focused on circular motion and the concepts of centripetal and centrifugal forces. The key is to master each topic individually before going to the next.

**3. Practice and review your math skills:** Since physics is applied math, being deficient in your aptitude in math will be a detriment in your ability to solve problems in physics. Review your math skills especially in the areas of advanced algebra and trigonometry. Also, review graphing methods for polynomial expressions and trigonometric functions. More importantly, know how to graph equations in both Cartesian ($x$, $y$, $z$) and Polar coordinates ($r$, $\theta$, $\phi$). Polishing up your adeptness in math will ensure a much smoother transition in applying it to physics and will improve your chances of getting a higher score on the AP Physics exam.

**4. Practice drawing diagrams and graphs:** Data is more easily recognized if it is done diagrammatically or on graphs and plots. When doing problems dealing with inclined planes, always create a drawing within a Cartesian coordinate system and label all of the forces and their component (x and y) parts. Place ALL the data given in the problem onto the diagram. As you are solving the problem, place any interim data that you have calculated onto it as well. If you do it this way you will not get lost or waste valuable time working out the details.

**5. Perform each problem in a step-wise fashion:** This is especially important for the FRQ portion AP Physics exam. The multiple-choice questions can be done as you would normally do on any exam. The FRQs require you to follow a logical and step-wise process. Remember, you are utilizing several concepts or equations to answer multiple questions (usually 4 or 5). Follow a natural progression when solving the problem and try not to skip any steps.

# The Ultimate List
# of AP Physics 1 & 2 Tips Cont.

**6. Understand what the equations mean:** The great thing about the AP Physics exam is that they actually give you all of the equations, constants, etc. that you will need for solving each problem on the exam. You really don't need to memorize the equations, but rather, you need to know what they say and how to use them. The reason they do this is because they are trying to assess how deep your understanding of physics is and not how good your memory is. The only downside to this is that the problems will be harder to solve. At least they give you a crutch to help you concentrate more on the underlying principles and concepts of physics which is exactly what they should be doing anyway.

**7. Identify the topics you have difficulty with:** When solving problems, you may very likely come to a road block. You may be stuck for one or both of the following reasons:

a. You don't know what equation(s) to use. In this case, do the following. Write down the given variables and their numeric values from the question. Next, go to the list of equations **here** (listed in the Appendix on page 225) and identify which equation uses those **given** variables **and the variable that you need**. Doing this will identify at least one or two equations as possibilities. Choose the equation(s) and attempt to solve the problem again. If you are still having trouble, review the basic concepts for the specific topic and try again.

b. You know what equation(s) to use but you seem to be missing a variable or two. This usually happens when you are presented with a large word problem such as those in the FRQs. Often times they will not explicitly give the variables you need. Instead they will use wording that you need to dissect in order to extract the variable. For example: A car traveling north for 30 km reaches its initial destination in 30 minutes. It then changes course and travels at 40 km east and reaches its final destination in 30 minutes. Using vector addition, find the resultant velocity of the car.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

For this question you need to calculate the two velocities (north and east) individually and perform the vector addition. So the two velocity vectors to add are:

$$\vec{v_N} = \frac{30km}{0.5hr} = 60\frac{km}{hr}North$$

and

$$\vec{v_E} = \frac{40km}{0.5hr} = 80\frac{km}{hr}East$$

For this question you need to calculate the two velocities (north and east) individually and perform the vector addition. So the two velocity vectors to add are:

$o\vec{v_R} = 100\frac{km}{hr}$ in the direction 53.13º east of north.

**8. Know and understand the common units for the variables of each equation:** The units of each variable in an equation should be known and understood. There is an entire section of physics known as unit or dimensional analysis. When you perform a complex calculation you need to follow through on your units. See this **website** for more about dimensional analysis.

**9. Label all vectors properly:** Many students lose valuable points on the AP Physics exam by leaving out the small arrows above the variable letter of a vector and by leaving out the direction of that vector.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

Always place a small arrow above the **<u>variable's letter</u>** if it is a vector quantity **<u>and indicate its direction</u>**. See some examples below:

$$\vec{v} = 80\frac{km}{s} \quad Northeast;$$

$$\vec{a} = 30\frac{km}{s^2} \quad at\, 60°$$

$$\vec{a} = 20\frac{rads}{s^2} \quad at\, 45°$$

**10. Use negative g (a= -g) in acceleration due to gravity equations:** This is a very common mistake by students in physics. When using equations involving the acceleration due to gravity, remember to change the sign from positive to negative in the equation. The force of gravity and the acceleration due to gravity points down towards earth and thus needs to be a negative value in these equations.

**11. Conservation of Energy applies to everything!** There are applications to this main concept all over the AP1 exam… including applications to kinematics (projectile motion). Even in kinematics, you can use the idea of conservation of energy, and then cancel the masses to solve. Thanks for the tip from Kristin C. at Southwest High.

**12. I would recommend that students practice working at a pace that is comparable to the AP PHYSICS 1 time frame.** For example, if you know the AP test is 6 Free Response problems over the course of 90 minutes, then practice doing 1 Free Response problems in a span of 90 minutes divided by 6 problems. The worst scenario is a student not understanding the pacing needed to adequately work through the test. Thanks for the tip from Douglas P. at Upper St. Clair High.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**13. If you're absolutely stuck, try conservation of energy!** As long as the problem isn't a collision problem, you should be okay! Thanks for the tip from Melissa D.

**14. Learn how to use a scaffolding equation to help make decisions.**(i.e. if P triples while T is increased by a factor of 15 what happens to the volume of an ideal gas in a sealed container. Writing out the scaffold $PV = nRT$ or $PV = NkT$ will provide a good framework for working out the solution)Thanks for the tip from Ari E.

**15. I think with AP Physics 1 and 2 there should be less of an emphasis on mathematical skills and more an emphasis on conceptual understandings.** I would say a great token of advice would be to solve every conceptual question in your Physics book. I try to assign many of them for my AP students and it generates a lot of discussion. Class discussions over the questions usually lead students to have a deeper understanding of the Physics concepts. My tip: **Solve as many conceptual questions as possible.** Find more online and solve those. Challenge your classmates by thinking up "what if" questions. Thanks for the tip from Ross G.

**16. Generate a plan.** Schedule time to study that isn't part of your typical study time for class. Maybe preview new material before you get there. Inside of your study plan, students should develop methods for assessing their knowledge. Then based on their self assessment, they should re-design their plan to help themselves master the concepts. Most importantly, student should NOT try to cram. Physics is a subject that you cannot cram for. What you know on test day likely was developed months in advance. Thanks for the tip from Ross G.

**17. Knowing the fine details of a concept is what really gives insight into difficult problems.** Thanks for the tip from Bill S. at AC Reynolds High.

**18. Do your algebra, show your work.** Thanks for the tip from Eric T. at Rocky Mountain.

# The Ultimate List
# of AP Physics 1 & 2 Tips Cont.

**19. Keep It Simple Silly!** – With every complex question, it can be broken down into the different simple concepts and then solved using those concepts. The questions are not there to trick or confuse you, but to give you an opportunity to show your knowledge. Break it down and show every step along the way. K.I.S.S. Thanks for the tip from Andrew C. from Canyon Crest Academy.

**20. Care must be taken to be proficient at completing questions quickly without sacrificing accuracy.** Students who excel on the exam have figured out how they can identify what a question is asking and then answer it quickly without making the errors many students make when they start to race against the clock. Thanks for the tip from Takoa L.

**21. Avoid pronouns in the writing section and end your conclusion in the experiment question with "if the data gives this then the conclusion must be that the claim is true.** If the data says instead that then the conclusion is false." Use if-then statements to bring together results and conclusions. Too many students lost points on last year's circuit question AP 1 because they did not attach a conclusion at the end of the result statement. Thanks for the tip from Wayne M.

**22. For the same scenario/problem, 1) Explain what is happening in words, 2) Prepare graphs of what is happening,3) Use formulas to calculate what is happening, & 4) Connect the verbal, graphical and algebraic descriptions.** Thanks for the tip from Beau W.

**23. On the AP test, write down every step.** Pretend your grader doesn't know anything about physics. This way you cover all conceptual ideas. Thanks for the tip from Rachel H.

**24. Physics is more than plugging just numbers into equations.** It is understanding the meaning behind those equations and conceptualizing the problem (with drawings) to know which numbers are appropriate with which equations. Thanks for the tip from Lena E. from La Cueva High.

# The Ultimate List of AP Physics 1 & 2 Tips Cont.

**25. Don’t memorize how to do problems.** Use the laws and principles to get your solutions from scratch. Thanks for the tip from Todd C. from Brea Olinda High.

**26. Never sit and stare at a problem**– Have a plan and follow the plan- Identify what you know, draw a diagram, identify the topic, use an equation if necessary, show your work… Thanks for the tips from Stacy S.

**27. Annotate and review your equation sheet**. I have my students write out “key words” that indicate a certain type of problem on their equation sheet. They practice, review and re-write their annotated equation sheet through out the year to help remind them of all topics through out our course of study so nothing goes too long without being reviewed. Thanks for the tip from Stacy S.

**Are you a teacher or student? Do you have an awesome tip? Let us know!**

The AP Physics exam is notorious amongst the AP science exams for its tough content and extensive reading list. Still, every year thousands of students take this course and pass the exam, earning valuable experience with complex physics in addition to college credit. If physics is your passion and you hope to study it at the college level, or even if you just really love physics and are looking for another outlet, this course and exam is for you. Don’t get bogged down in the details of the exam but enjoy the problems that you solve and study in class. Think about them in terms of their amazing scientific contributions to today’s technological advancements. Get lost in the amazing power of physics and you will undoubtedly find success on the AP Physics exam.

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