AP Physics C: Mechanics

2024-2025 Summer Work

Mr. Bliss

Students,

Welcome to AP Physics C! I can't wait to get started working with you all on this exciting and challenging subject! Many of the topics that we will be covering throughout the year are ones that you have already seen in Physics 1, but we will be going a bit more in depth with them, analyzing scenarios that are more complex, and introducing Calculus into our understanding of these physics principles. The class contains an emphasis on lab practices and "doing the work of scientists", so be prepared to complete two or so labs per unit which will involve experimental design, data collection and analysis, and various means of communicating experimental results. The course will cover the following units:

1. Kinematics
2. Force and Translational Dynamics
3. Work, Energy, and Power
4. Linear Momentum
5. Torque and Rotational Dynamics
6. Energy and Momentum of Rotating Systems
7. Oscillations

Although physics is not just merely another math course, a strong foundation in math is needed to be successful. The attached summer work serves as a review of key concepts in algebra and trigonometry that will recurringly be needed throughout the year. It is assumed that you will be confident using these math skills by the first day of the school year. There will be a quiz on these math skills within the first two weeks of school. If you would like additional practice with these topics/want more in depth explanations than what are provided in this packet, there are numerous great tutorial videos available on YouTube to further your understanding of them. If you would like me to steer you in the direction of some high-quality resources, please reach out to me. This packet will be due Tuesday, August 27th (day before school starts) and graded for completion. Looking forward to a great year! Please reach out if you need anything!

Best,
Mr. Bliss
(cbliss@stjohnschs.org)

Directions for Math Review Packet

On either paper or a Notability doc, clearly number each problem and SHOW YOUR WORK for each solution (pretend as if this was a test/quiz/AP exam). Problems without work shown will NOT receive credit.

When you have completed the assignment, email your work to Mr. Bliss at cbliss@stjohnschs.org. It will be due Tuesday, August 27th and will count as your first homework assignment.

An answer key will be posted during the first week of the school year for you to check your work.

Important Math Skills

To succeed in AP Physics, you will need to master the following skills. By "master", I mean you'll need to use them confidently without having to stop and think or referring to equations.

1. Scientific Notation.
2. Units: converting units, applying metric prefixes, and finding the units that result from mathematical operations.
3. Algebra: Solving single and simultaneous equations.
4. Geometry/Trig: Breaking angled quantities into right-angle quantities and recombining right-angle quantities into angled results.
5. Basic physics: Finding density from basic amounts and finding amounts from density.

Skill 1: Scientific Notation

It's assumed that you're already comfortable with scientific notation. You will need to carry out many detailed calculations using scientific notation. You will need to develop the ability to quickly perform "order of magnitude" calculations using only the powers of ten. This will help you to anticipate the approximate size of the answer and ensure that your more detailed calculations are correct.

Skill 2: Units

Manipulating Units:
In physics, we have common units in which we measure variables. For example, displacement is measured in meters (m), time is measured in seconds (s), and mass is measured in kilograms (kg). Units just multiply and divide algebraically, so velocity (which is displacement divided by time) has the units of m/s.

Metric Prefixes:
To measure different quantities conveniently, we modify the basic units using metric prefixes. You can certainly apply the prefixes using Unit Conversions (see below), but it's preferable to be able to decode the prefixes without doing a formal conversion.

Factor	Prefix	Symbol
10^9	Giga	G
10^6	Mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p

To convert a metric measurement quickly, first memorize the table of prefixes. Then use your head! You need a lot of small things to equal fewer big things. That will tell you whether to multiply or divide by the factor.

Example: to convert 4.7 km to meters, the factor is 10^3. Do we multiply or divide? Well, meters are smaller than km, so we need a lot of meters to make up a km. It makes sense to multiply by 10^3. We end up with 4700 m.

Example 2: to convert 80 nm to meters, the factor is 10^{-9}. Meters are bigger than nm, so I need a smaller number. I would multiply by 10^{-9}, making a smaller number ($8x10^{-8}$ m).

Answer the following numbered problems on your piece of paper/Notability doc.

1. How many centiliters (cL) in 150 liters?

2. How many kilometers (km) in 0.001 mm?

3. How many Newtons (N) in 12.68 x 10-5 GN?

<u>Unit Conversions</u>

Sample equalities: 1 meter = 39.37 inches
12 inches = 1 ft
1 pound = 4.448 newtons
1 mile = 1.61 km

The way that I advocate doing conversions is by setting up an algebraic equation. For instance, let's say that I want to convert 20 inches to nanometers.

$$20 inches\left(\frac{1 meter}{39.37 inches}\right)\left(\frac{1 nanometer}{10\text{^}-9 meters}\right) = 5.08 \text{ x } 10^8 \text{ nanometers}$$

Notice that the first number and the last number are physically the same quantity. The items in parentheses are mathematically equal to 1, since the numerators equal the denominators. You can see that the inches on top and inches on the bottom cancel out, and so do the meters, leaving you with nanometers.

4. How many centimeters are in 48 inches?

5. How many inches are in 28nm?

6. How many pounds are in 600 Newtons?

7. How many miles per hour (mph) is 2.2 km/min?

Skill 3: Algebra

Proportional Reasoning/Analysis:
In Physics, we have a variety of equations that show the relationship between several variables. We often need to figure out what changing one variable will do to another variable, without knowing specific quantities.

One common relationship is F = m a, or net force = mass * acceleration. Let's say that we push a block of mass m with a force of F and it accelerates with a value of a.

8. If we push another block with mass 2m, how much force is needed to have the same acceleration, a?

9. What if we now push a block of mass 3m with a force of 2F. What will the acceleration be? (in terms of a, like 2a, 0.5a, etc)

10. $KE = \frac{1}{2} mv^2$. How much would the kinetic energy of an object change if it has 3 times the initial velocity?

Solving Systems of Equations
When we're solving problems involving systems of objects, we often write an equation for each object, ending up with multiple equations and multiple unknowns. To solve these equations, we need to combine them. There are a few ways to solve these problems. We'll only address the first 2 approaches here.

a. Rearrange one equation to solve one variable in terms of the other, then substitute into the other equation. (Substitution Method)
b. Multiply or divide one equation by a constant and then add or subtract equations to eliminate a variable. (Combination Method)
c. Graph the equations, find the intersection.
d. Use matrices in the calculator.

Take a look at this example:
Solve for x and y:
$5x – 2y = 15$
$7x – 5y = 18$
Substitution: The way that you were first taught to solve systems of equations was probably to do substitution; solve one variable in terms of the other and then substitute it in. This is most useful for simple equations.

If you solve for y in the first equation, you will get $y = \frac{5x}{2} - \frac{15}{2}$
Then substituting in y for the second equation, you find x = 3.54
Then by substituting x in for any of the above equation, you can find y =1.36 Check your answer by substituting your answers into the other equation; it should solve both equations.

Combining equations. Multiply each equation by a constant so one of the variables has a matching coefficient.
Starting with:
5x – 2y = 15
7x – 5y = 18

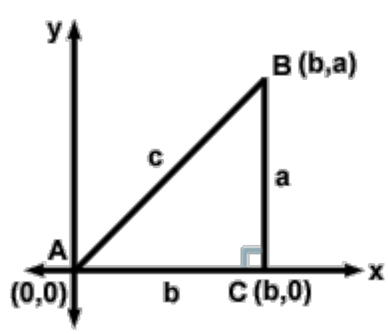
I'll multiply the top equation by 5 and bottom by 2 so the y variable has a coefficient of -10 in each equation.
25x – 10y = 75
14x – 10y = 36
Subtracting the bottom equation from the top, I get 11x = 39
So I can solve for x, and substitute that back into either equation to get y.

11. Solve for the (x,y) coordinate that satisfies both
    5x + y = 13
    3x = 15 – 3y

12. Solve for the (x,y) coordinate that satisfies both
    2x + 4y = 36
    10y – 5x = 0

Skill 4: Geometry and Trigonometry

Consider the right triangle pictured below:



Using the lengths of the sides of right triangles such as the one above, the trigonometric functions can be defined in the following way:

$a^2 + b^2 = c^2$

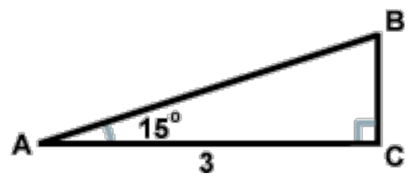
$$\sin(A) = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{a}{c}$$

$$\cos(A) = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{b}{c}$$

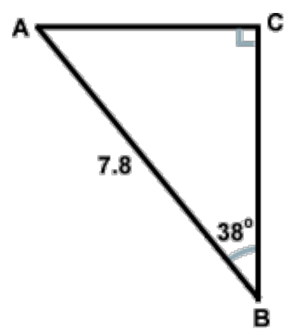
$$\tan(A) = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{a}{b}$$

Find the other lengths and angles of these triangles using the trig functions and/or the Pythagorean theorem.

13.

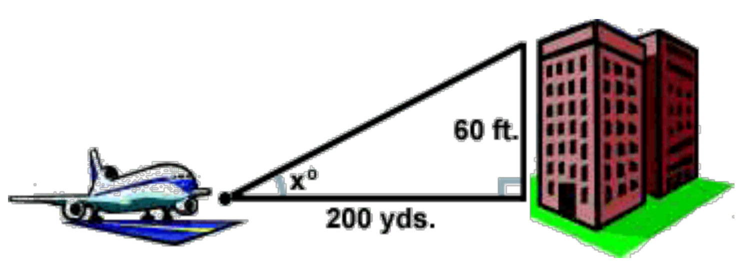


14.



If we know the sides, we can determine the angles. In the triangle above, if we know lengths AC and AB, we know the sine of angle ABC is AC/AB (opposite over hypotenuse). So the angle ABC is $\sin^{-1}$ (AC/AB).

15. An airplane takes off 200 yards in front of a 60 foot building. At what angle of elevation must the plane take off in order to avoid crashing into the building? Assume that the airplane flies in a straight line and the angle of elevation remains constant until the airplane flies over the building.



Vectors

In Physics, vectors are quantities that have direction. For example, temperature is not a vector because it doesn't have a direction. Forces are vectors, because it matters which direction the forces push. (Example: 32 N at an angle of 27 degrees)

One way we add vectors is by separately adding horizontal components (how much the vector goes horizontally) and vertical components. The vector sum is called the resultant.

To combine these two vectors, we would first find the x and y components of each vector. Using trig we get:

To add the vectors, you combine the components in the x direction (17.3 N right and 9.4 N left would be 17.3 – 9.4) and in the y direction (10 N down and 3.4 N down would be –10 – 3.4)

So there would be a net of 7.9 N to the right and 13.4 N down.

Using the Pythagorean theorem and then finding the inverse tangent of 13.4/7.9, we would get a magnitude of a 15.6 N force directed at an angle of about 60 degrees below horizontal.

16. A plane is flying 50 m/s in a direction 30 degrees north of east. A sudden wind starts blowing at 15 m/s in a direction 50 degrees south of east.
    a. Draw a picture of the situation
    b. Break the vectors into east/west components and north/south components
    c. Add the components to get the net in the east/west direction and north/south direction
    d. Find the magnitude of the net speed by using the Pythagorean theorem
    e. Find the direction that the plane ultimately travels in using a trig function

17. Add the following vectors and determine the resultant.
    3.0 m/s at a 45 deg angle and 5.0 m/s at a 135 deg angle

18. Add the following vectors and determine the resultant.
    5.0 m/s at a 45 deg angle and 2.0 m/s at a 180 deg angle

Skill 5: Density

Population density is the number of people per unit area. In physics, density functions are often used for mass densities, charge densities, and current densities. Density is a measure of stuff per unit space. The one you are most familiar with is mass density (which is mass/volume). You can also have one- and two-dimensional densities.

Linear mass density $\lambda = \frac{m}{l}$ (mass/length) λ = lambda

Surface mass density $\sigma = \frac{m}{A}$ (mass/ area) σ = sigma

Volume mass density $\rho = \frac{m}{V}$ (mass/volume) ρ = rho

Common Volume and Area Equations

Volume of a sphere: $\frac{4}{3}\pi r^3$

Surface area of a sphere: $4\pi r^2$

Volume of a cylinder= $\pi r^2 h$

Surface area of a cylinder: $2\pi rh$ (for the sides) + $2\pi r^2$ (for the ends)

19. An iron sphere has a mass density of $\rho = 7.86 \times 10^3$ kg/m^3. If the sphere has a radius of 0.5 m, how much mass does the sphere contain?

20. A sphere made out of material x has a mass of 5 kg and has a radius of 4m. How much mass does a sphere of the same material with a 3 m radius have? (hint: since they are the same material, they have the same density)

21. A sphere made out of material y has a mass of 6 kg and has a radius of 3m. How much mass does a cylinder of the same material with a 4 m radius and a 2 m length have?

AP Free Response Questions (FRQs) make up a significant portion of the AP exam in May. Please read over and familiarize yourself with the common AP Task Verbs that are contained in these FRQ problems.

1. AP EXAM TERMINOLOGY: On the Free-Response section of the AP Physics Exams, the words that command the student all have precise meanings. These words are explained in this section.

Describe and/or **Explain** natural phenomena – This response primarily requires the use of words. State basic principles or laws of physics as complete sentences. Then use additional sentences to connect those physics principles to what is observed related to this phenomena.

Justify a response – This response primarily requires the use of words, but may refer to equations, data, or graphs. To justify an answer is to give an argument in favor of the answer based on evidence. Start by stating basic principles of physics as complete sentences. Then clearly state the evidence (equations, calculations, data, graphs) that is relevant to the physical principles. Then connect the principles and evidence to the answer.

Calculate a quantity – This response primarily requires the use of mathematics, but using words to explain steps is strongly encouraged. If a problem uses the word "calculate", then the student is expected to show work leading to a final answer. *Note*: It is almost impossible to follow, understand, and give partial credit to any work that is made up entirely of numbers. It is for this reason that using words to explain steps is so important.

Derive an expression – This response primarily requires the use of *symbolic* mathematics. Although words can be used to explain steps, it is less necessary to use words since symbolic equations are much easier to follow than work consisting of numbers. If a problem uses the word "derive", then the student is expected to start with one or more equations on the official AP Physics Table of Equations. The student then manipulates the symbols of the equation(s) to obtain an expression as the final answer.

"**What Is**" and "**Determine**" an answer – This response may be words or math depending upon what is asked. These words indicate that work shown or justification is not necessary to receive full credit. However, in some cases, "what is" and "determine" questions carry multiple partial-credit points. A wrong answer with no supporting work or words always receives zero points. However, a wrong answer with some correct supporting work or justification can receive partial credit. Therefore, it is still worth showing work or justifying with words a "what is" or "determine" response.

Sketch a graph – Draw lines or curves on the axes in order to illustrate a particular trend or relationship. Both axes should be labeled with either words or symbols to represent the quantities being graphed. Depending on the situation, the axes may require one or more values to be labeled. These values may be important intercepts, asymptotes, maximum values, or minimum values. If any numbers are written on a graph, then units must be indicated somewhere.

Plot a graph – The student is given data points that are the results of some experimental procedure. The student is expected to place dots on a grid, one dot representing each data point. The axes of the grid must be given a linear scale (that means that the numbers on the scale increase by the same amount each step), the axes must be labeled with words or symbols representing the units being plotted, and units must be indicated.

Draw and Label the Forces – In problems where Newton's Laws must be used to analyze a situation, the student will be asked to draw and label the forces acting on an object. A dot will be provided and the student must draw arrows originating on the dot and extending in a straight line in the direction that the force acts. See "Free-Body Diagrams" for important notes.

Design an experiment or **Outline** a procedure – In either paragraph or outline form, the student is to provide an orderly sequence of steps necessary to collect data to answer a scientific question. The procedure should include what equipment is to be used, how the experiment is to be set up (or a diagram), and what measurements are made (and how measurements are made and what equipment is used to make each measurement).

Final Part of Assignment

Reflection Questions:

1. On a scale of 1-10, how confident did you feel with these practice problems?
2. Which topic did you find the most challenging/needed the most review with?
3. How are you feeling about taking AP Physics C?
4. Is there anything that you are worried about for the upcoming school year?
5. Is there anything else you would like me to know?

If you would like to get ahead and review the first two topics we will cover this year (Kinematics and Newton's Laws), the following are great resources (OPTIONAL)

Kinematics Review by Flipping Physics: https://www.flippingphysics.com/apc-kinematics-review.html
Newton's Laws (Dynamics) Review by Flipping Physics: https://www.flippingphysics.com/apc-dynamics-review.html

*Since most of you will concurrently be taking Calculus, it is NOT expected that you have a foundation in derivatives and integrals by the first day of school. We will be going through an overview of Calculus principles in Physics (supplemented by what you are studying in Math) whenever we reach material that requires it.

Additional Resources:
All of Flipping Physics videos geared towards the AP Physics C Exam (more in depth and broken down into smaller sub-topics): https://www.flippingphysics.com/ap-physics-c.html#kinematics

Viren's Physics Videos geared towards the AP Physics C Exam (lecture style "whiteboard" notes broken down by unit and sub-topic): https://www.apphysicslectures.com/ap-physics-mechanics#h.p_XqshjQ-WHVsO