General Physics Study Guide

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1 Introduction

This study guide is for General Physics I & II. It covers basically all of the material in these courses. I can't guarantee it is all correct, but I think it's fairly comprehensive. I took that course during **Fall 2024 & Spring 2025** semesters, so that's when it was last updated. Material could have changed or been moved around since then. Also, just to flag, the material is not in the order that it was taught the year I took it. I grouped it based on concepts, rather than whatever the class does which I think is difficultly. As a result, you might encounter a really difficult topic out of nowhere. For example, Forces and Torques are similar concepts, but Forces is the second chapter and Torques is one of the last in the class. Despite that, I've decided to group them simply *because* they are similar topics. With that out of the way, I hope you find this guide helpful!

2 Prerequisite Math

Obviously physics needs a lot of math. This section covers is mostly about vector math you'll need for this course.

2.1 Special Angles

Here are very common angles that may be asked of you. It's best to memorize these angles and their values when trigonometric functions are used on them. These angles are reference angles, and because of that, they only represent magnitude. You need to add the sign after you are done computing the value based on what is physically happening in the scenario/question.

Operation	$0° = 0$	$30° = \frac{\pi}{6}$	$45° = \frac{\pi}{4}$	$60° = \frac{\pi}{3}$	$90° = \pi$
$\sin(\theta)$	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
$\cos(\theta)$	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0
$\tan(\theta)$	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	undefined

2.2 Basic Vector Operation

A vector is a way to store numbers. In a physics sense, it's really just an arrow pointing from one place to another. Below are vector basics including how to add and multiply vectors. This covers all important vector operations done in this course. A normal number like 5 is called a scalar. In this class if something is not a vector, then it is a scalr.

2.2.1 Representing Vectors and Magnitude

Let $\vec{A}$ be a vector of 3 dimensions.

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k} \tag{1}$$

There are other ways to represent vectors, but this is the way we'll do it in this class. Each $A_{something}$ literally just represents the x, y, or z coordinate of the arrow's tip.

A quick notational thing is the difference between $|\vec{A}|$ and $\vec{A}$. The first one represents the magnitude while the second one is the actual vector. If you think about our arrow representation, the magnitude of a vector is literally just how long it is. In a 2D space, if you think about a triangle, think about it as finding the hypotenuse from the length of the base and height. In fact, to find the magnitude of a vector from its normal form, you just use pythagorean's theorem. Below is that theorem in three dimensions.

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2} \tag{2}$$

2.2.2 Vector Addition and Subtraction

$$\vec{A} \pm \vec{B} = \langle \vec{A}_x \pm \vec{B}_x,\ \vec{A}_y \pm \vec{B}_y,\ \vec{A}_z \pm \vec{B}_z \rangle = \vec{C} \tag{3}$$

2.2.3 Vector Multiplication

Vector multiplication comes in three flavors: multiplication by a scalar, the dot product, and the cross product. Scalar multiplication is multiplication between a scalar and a vector. The other two occur between two vectors. On a super high level, the dot product results in a scalar, whereas the cross product creates another vector.

Scalar Multiplication. Multiplying a vector by a scalar is by far the easiest vector multiplication. Suppose n is a scalar (that is, n is some number).

$$n\vec{A} = (A_x \times n)\hat{\imath} + (A_y \times n)\hat{\jmath} + (A_z \times n)\hat{k} \tag{4}$$

You basically just distribute it over the vector.

The Dot Product. There are two ways to calculate the dot product.

$$\vec{A} \cdot \vec{B} = (\vec{A}_x \times \vec{B}_x) + (\vec{A}_y \times \vec{B}_y) + (\vec{A}_z \times \vec{B}_z) \tag{5}$$

$$\vec{A} \cdot \vec{B} = |\vec{A}| \times |\vec{B}| \cos\theta \tag{6}$$

This is the second equation solved for theta, which often comes in handy.

$$\theta = \cos^{-1}\left(\frac{\vec{A} \cdot \vec{B}}{|\vec{A}| \times |\vec{B}|}\right) \tag{7}$$

The Cross Product. There are also two ways to calculate the cross product. A quick note: when you do the cross product of two 3D vectors, your resultant vector (the output) will be one dimensions smaller.

$$\vec{A} \times \vec{B} = |\vec{A}||\vec{B}| \sin\theta \tag{8}$$

$$\vec{A} \times \vec{B} = (A_y \times B_z - A_z \times B_y)\hat{\imath} + (A_z \times B_x - A_x \times B_z)\hat{\jmath} + (A_x \times B_y - A_y \times B_x)\hat{k} \tag{9}$$

This formula will be used a lot less. In fact, you'll almost never use it.

3 Kinematics

Kinematics refers to the process of figuring out how something moves over time, including its velocity and acceleration.

3.1 Primer: Translational and Rotational Motion

Before discussing how to actually do kinematics, we'll start by talking about the two types of motion studied in this class: translational and rotational. **Translational** motion refers to things moving in a line or curve. For example, a car driving down the highway or a ball being thrown between two people. **Rotational** motion refers to the motion of something spinning such as someone on a merry go round or a pulley.

Something can have one and not the other, both, or neither. If I have a bowling ball in my hand and I'm just holding it, then it is stationary, so it has no motion. If I begin to spin the bowling ball on the floor and it stays in place, then it has rotational but not translational motion. If I slide it (that is, it's not rolling, the holes are always at the top for instance) then it has translational but not rotational motion. If I throw it down the alley and its rolling as it barrels towards the bowling pins, then it has both types of motion.

3.2 Primary Kinematic Equations

We start with $\vec{r}$ which represents position in a unit of distance (m). Before we begin, this variable is a little weird. In most of the equations given, you won't see a $\vec{r}$ because things will be generalized in one dimension. Just understand that $\vec{r} = x\,\hat{i} + y\,\hat{j} + z\,\hat{k}$.

We can think about our kinematic equations in very general terms using derivatives. The core kinematic equations are as follow.

$$\vec{v} = \frac{\mathrm{d}\vec{r}}{\mathrm{d}t} \tag{10}$$

$$\vec{a} = \frac{\mathrm{d}\vec{v}}{\mathrm{d}t} \tag{11}$$

3.2.1 Special Case: Constant Acceleration

Then, we have the constant acceleration equations which is what you'll use more often.

$$\vec{v}_f = \vec{v}_i + \vec{a}t \tag{12}$$

$$\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2 \tag{13}$$

$$\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}(\vec{r}_f - \vec{r}_i) \tag{14}$$

3.2.2 Relative Kinematics Based on Postion

Since positions are relative, we can deduce the relative speed of an object A relative to a Point B if we know the speed of A relative to a position C and the speed of C relative to B's position. This applies to position, velocity, and acceleration. To solve for this, we can use the following formula.

$$v_{\frac{A}{B}} = v_{\frac{A}{C}} + v_{\frac{C}{B}} \tag{15}$$

3.3 Rotational Kinematics

Just a quick note before this section begins. Appendix **??** contains a useful chart that summarizes all of the translation and rotational counterparts. The section below provides a slightly more in-depth look at the topic, including useful formulas, but if you're just trying to remember what the rotational counterpart to displacement is, you might be better off checking the chart.

3.3.1 Introducing Rotational Kinematics

Rotational kinematics operate in practically the same way as translational kinematics, but deals with objects that are spinning or otherwise moving in a circular motion. Below, we detail how you can take tangential measurements and turn them into their rotational counterparts.

$$\vec{s} = r\theta$$

$$\vec{v} = r\omega$$

$$\vec{a} = r\alpha$$

$$t = t$$

In these equations, $\vec{r} = \vec{s}$ for clarity's sake because the r that is included actually refers to the path's radius. Both $\vec{r}$ and $\vec{s}$ mean position. You would refer to each counterpart as the "angular" version of the translational one (ex. displacement becomes angular displacement).

3.3.2 Primary Rotational Kinematics Equations

Since we have already defined θ as angular displacement (in radians) we can define the other kinematic values.

$$\omega = \frac{\mathrm{d}\theta}{\mathrm{d}t} \tag{16}$$

$$\alpha = \frac{\mathrm{d}\omega}{\mathrm{d}t} \tag{17}$$

3.3.3 Special Case: Constant Rotational Acceleration

Now, we can combine the special case kinematic equations found in 3.2.1 with the definitions that relate the translational and angular values in 3.3.1. The process is simple, since the angular form of a kinematic value is the just the translational counterpart divided by r, we can just divide each of the 3.2.1 equations by r to create rotational counterparts.

$$\omega_f = \omega_i + \alpha t \tag{18}$$

$$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2 \tag{19}$$

$$\omega_f^2 = \omega_i^{\ 2} + 2\alpha(\theta_f - \theta_i) \tag{20}$$

3.3.4 Period and Frequency

As an object rotates around itself (or travels in a circular path), it's bound to come back to the same point eventually. Note that this only works for zero acceleration otherwise the time to finish one rotation would keep changing and that defeats the purpose of calculating such a measurement in the first place.The time it takes for one full rotation (usually called a cycle) is called the *period*, recorded in some unit of time.

$$T = \frac{2\pi}{\omega} \tag{21}$$

Frequency is the inverse of the period, defined as the number of rotations an object makes in one unit of time. Below are definitions of both in relation to angular velocity and each other.

$$f = \frac{1}{T} \tag{22}$$

An important thing to note is the unit of frequency. Since it's the inverse of T, its units are technically just "cycle per unit time", but if the unit of time is seconds, then we the unit hertz (hz). In other words $hz = \frac{1}{s}$.

3.3.5 Centripedal Acceleration

Centripetal acceleration, or rotational acceleration, is another important value that is unique to rotational motion. In effect, it is the inward acceleration that keeps an object that is moving in a circular path in that path. For example, you might be swinging a ball on a string in a circle; the reason it doesn't fly out is because the sting is applying a force (and therefore accelerating the ball) back into the circle as tangential velocity "tries to get it" to fly out. We can define centripetal acceleration using both tangential velocity and angular velocity.

$$\vec{a}_c = \frac{\vec{v}^{\,2}}{r} = \omega^2 r \tag{23}$$