

Learning Physics Topics for Machines

Ian Emmons

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1 Introduction

In 2021, the Science Olympiad Machines event includes a test on simple and (in Division C) compound machines (see rules 4.I.c and 4.I.d). The topic of simple and compound machines is a subset of the field of Physics, and specifically of the portion of Physics called Newtonian (or Classical) Mechanics. This means that test questions will contain bits and pieces of the topics listed in rule 4.I.e.:

1. Kinematics, position, speed, velocity, and acceleration
2. Newton's laws of motion and action-reaction
3. Inertia and momentum
4. Force and impulse
5. Kinetic and potential energy
6. Conservation of energy and momentum

This document is intended to help students study for these topics in preparation for the Machines test.

2 General Advice for Learning Physics

There are several excellent introductions to the field of Newtonian Mechanics for beginners, and we will talk about them below. But first, a few words about how to approach them.

Many people try to approach the study of Physics by memorizing a lot of formulas. Richard Feynman, a famous physicist, once told his students:

It will not do to memorize the formulas, and to say to yourself, “I know all the formulas; all I gotta do is figure out how to put ‘em in the problem!” Now, you may succeed with this for a while, and the more you work on memorizing the formulas, the longer you’ll go on with this method — but it doesn’t work in the end.

The problem here is that memorizing a lot of equations doesn’t help you understand what they mean, how they connect with each other, or how to use them to solve problems. It’s like looking at a cathedral but seeing only 100,000 stones.

The better way to learn Physics is to focus on solving as many problems as you can. At first this is hard, but don’t be discouraged, and don’t give up too quickly. Wrestle with each problem for a while, and then if you still have trouble, look at someone else’s solution. Soon, you will get the hang of it. This approach will help you much, much more than memorization. (And it will also help you to memorize the equations at the same time!)

Finally, don’t leave this work until a week before your tournament. There is too much here to learn in that short time.

3 Suggested Curriculum

One excellent physics resource for beginners is the Khan Academy:

<https://www.khanacademy.org/science/physics>

This does not assume that you know a lot already, so it’s perfect when you’re starting out. You will need to be able to do a little bit of algebra, like solving a simple equation in one variable. Along the way they teach the additional math you need for the physics, like vectors and vector components, plus a little bit of trigonometry.

Don’t skip the practice sections and quizzes: These are the most important part of learning physics!

Here is a list of the Khan Academy topics that teach the mechanics topics in Machines rule 4.I.e:

One-dimensional motion:

- Introduction to physics: All topics
- Displacement, velocity, and time: All topics
- Acceleration: All topics
- Kinematic formulas and projectile motion: All topics
- Old videos on projectile motion: Solutions to additional problems — useful to firm up your learning so far. But if everything is clear, you can skip these.

Two-dimensional motion:

- Two-dimensional projectile motion: All topics. These are important for learning the math you need for two dimensions, including just enough trigonometry for this event.
- Optimal angle for a projectile: All topics. These solve an important problem in physics. Don't be scared by the word "calculus" in the last topic — you won't need to know this in Machines, but it's easy to follow along and will build your physics intuition.

Forces and Newton's laws of motion: Until now, you've been learning a little physics and a lot of math. In this unit you finally have most of the math tools you need, and you'll dive into much more physics!

- Newton's laws of motion: All topics — this is the core of the physics we are learning for Machines
- Normal force and contact force: All topics — especially important for Machines!
- Balanced and unbalanced forces: All topics — especially important for Machines!
- Slow sock on Lubricon VI: All topics — a thought experiment to boost your physical intuition
- Inclined planes and friction: All topics — especially important for Machines!

- Tension: All topics — especially important for Machines!
- Treating systems: All topics

Centripetal force and gravitation: These topics are important parts of Newtonian Mechanics, but they are less likely to play a role in problems about simple and compound machines.

Work and energy:

- Work and energy: All topics
- Springs and Hooke’s law: All topics
- Mechanical advantage: All topics

Impacts and linear momentum:

- Momentum and Impulse: All topics
- Elastic and inelastic collisions: These topics are important parts of Newtonian Mechanics, but they are less likely to play a role in problems about simple and compound machines.
- Center of mass: Watch the first video, “Center of mass,” because that will give you a good intuition for this important topic. However, the other topics (“Equation for center of mass” and “What is center of mass?”) are more than we need for Machines.

Torque and angular momentum: These topics are an important part of Newtonian Mechanics, but they are less likely to play a role in problems about simple and compound machines.

(Skip a bunch)

Discoveries and projects: Only one of these is relevant.

- Simple machines explorations: Read “Simple machines and how to use this tutorial” first, then read the rest for an introduction to three of the simple machines.